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# FEASIBILITY AND DESIGN STUDY - 240 TON PER DAY WOOD REFINING DENSIFICATION FACILITY WITH 2.0 MEGAWATTS COGENERATION FOR EUREKA, MONTANA

*Prepared for*

*MONTANA DEPAPTMENT of NATURAL RESOURCES and CONSERVATION*

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# FEASIBILITY AND DESIGN STUDY - 240 TON PER DAY WOOD REFINING DENSIFICATION FACILITY WITH 2.0 MEGAWATTS COGENERATION FOR EUREKA, MONTANA

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April, 1983

Prepared for

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# ABSTRACT

This study explores the technical and economic feasibility of constructing a densified wood fuel facility with cogeneration. Facility design is for a site in the Eureka, Montana area. Raw material resources were investigated in this area. Economic analyses were performed for a 2 megawatt, 11 ton/hr plant. Capital and operating costs, financing methods, and marketing considerations were explored.

Conclusions:

1. Raw material supplies in the Eureka area could presently sustain the plant operation.
2. Future dependability of raw material supply would be enhanced through developing in-woods collection relationships with the United States Forest Service.
3. Conventional wood refining facilities exist to demonstrate technical feasibility. All engineering studies indicate that the cogeneration system is also technically feasible.
4. The facility is both environmentally and economically feasible if the plant can operate at a capacity factor of 70%.

Recommendations:

1. More detailed marketing analyses need to be performed to ensure full production of plant can be sold.
2. Feasibility studies should be performed for down-sized facilities. Research indicates that identical facilities of one fourth to one half the production capacity of that proposed can be economically viable. Other communities in Montana which may support down-sized facilities include Missoula, Bozeman, and Helena.
3. Economic analysis indicates that financial success of the proposed facility could be enhanced through design changes to allow the cogeneration system to operate independently of the wood fuel refining facility. This would allow more continuous operation of the generator, resulting in reduced thermal wear and greater electricity production.

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# EXECUTIVE SUMMARY

# EXECUTIVE SUMMARY

This study has been prepared for the purpose of exploring the technical and economic feasibility of constructing a densified wood fuel facility with cogeneration in the Eureka, Montana area. The facility would produce an average of 1850 KW, 6000 hours of the year, in addition to approximately 11 tons per hour of wood fuel products. Inputs to the facility would consist of approximately 1300 KW electrical, and 21 tons per hour of raw material (often called "hog fuel") consisting of a combination of sawmill wastes and in-forest slash chipping production.

A site questionnaire was developed for the purpose of recording site specific data on several items: zoning, availability of water, proximity to utility lines, proximity to landfill sites, land use conformity, etc.

Sawmills within a 100 mile radius were contacted to develop data on resources available in the form of hogged bark and wood, sawdust, planer shavings and other miscellaneous residues such as slabs and edges. The results of these inquiries have been tabulated in Section 3.2, page 3-5. Contacts were established with the U.S. Forest Service to arrive at data on quantities of logging residues available in the local National Forest, or district, both present and future. These residues consist of cull logs, tops and limbs, and in some cases, stumps. At present, in-woods chipping operations to recover these residues produce an expensive raw material. The possibility exists, however, that some of the cost of collection and chipping could be offset by the U.S. Forest Service.

In addition to the State building permits , it is likely that the proposed facility would require at least the New Source Performance Standards (NSPS) review and possibly the Prevention of Signifcant Deterioration (PSD) review. Currently, the NSPS review is conducted by the State, and the PSD review by the federal government (Environmental Protection Agency). No permits to discharge liquid effluents or any toxic substances would be required.

Much negotiation remains to be done with the Lincoln Electric Cooperative (LEC) regarding interconnection agreements, responsibility for equipment, and rate structure. These negotiations would not be undertaken until such time as the facility was in the final stages of design. For the purposes of this study, the LEC Policy Bulletin on the subject of cogenerator interconnection has been included; this Policy Bulletin applies to cogenerators producing up to 50 KW: above this quantity, special negotiations have to be entered into. The Policy Bulletin, however, serves as a good indication of many of the general requirements.

The facility design incorporates standard grinding, drying, and pelletizing processes. The cogeneration system, however, is fairly complex, requiring special design considerations. Based on a survey of the available turbines, combustors, and other related component hardware, a 2.0 MW gas turbine/generator was selected. The unit ultimately selected was the Solar Turbines International Centaur unit, equipped for external firing (referred to as the Indirectly Heated Gas Turbine cycle, or IHGT). A rotary drum dryer uses the "waste" heat generated by the cogeneration system to dry the ground wood residues to a moisture content suitable for use as both cogeneration fuel and as feedstock for the pelletizing processes. Further grinding and screening is performed prior to burning and pelletizing.

The time span required for completion of the proposed project, from Preliminary Engineering through Start-up, is estimated to be 17 months.

Based upon a production year of 6000 hours (70% of year), the facility would generate approximately 64,800 tons of pelletized wood fuel and 11,100,000 KW-Hrs of electricity. At an estimated electricity sales price of $.037/KW-Hr, and a gate price of $60.00/ton for wood pellet fuel, gross annual income for the facility would be approximately $4.3 million. The estimated total of first costs for the facility is $4.6 million. The project financing has been assumed to consist of a debt/equity ratio of 70/30. At an assumed annual interest rate of 15%, amortizing the debt over 10 years provides an annual estimated net profit of $1.2 million. All of this is based on the assumption that the facility would operate at capacity for the stated number of hours per year and that a sufficient market would exist to absorb the annual production.

Marketing of electricity is a matter of negotiating rates for purchase and wheeling with the utility or BPA. In this study a figure of $.037/KW-Hr has been assumed. BPA would purchase the power generated. Fuel sales would be to Institutional, Commercial, and Residential consumers. Analysis shows that at least three "large" consumers (10,000 tons per year) would be needed, and the balance of the 64,800 tons/yr production would be sold to Commercial and Residential consumers.

# INTRODUCTION

This study was prepared to investigate the feasibility of a biomass densification facility producing 240 tons per day of pelletized solid fuel from wood residues, while producing a nominal 2000 KW of electrical energy through cogeneration. The electricity would be generated using a portion of the wood residues processed as fuel in an indirectly heated gas turbine (IHGT) cycle. The study also is intended to develop a design for the facility described above for a site in the Eureka area. Several sites are considered for their suitability in this application.

In addition to products marketing, the most critical consideration in the success of this type of facility is an adequate and ongoing supply of raw material. For this reason, data on available local sources of sawmill residues have been compiled. Due to the increasing number of facilities being built in the Pacific Northwest which will utilize hog fuel, and to greater hog fuel utilization within existing facilities, the future of quantities and prices for these residues is uncertain. It is fairly certain to assume that, as utilization of hog fuel and other industry-generated wood residues increases, prices will increase and availability will decrease. Because of this likelihood, we have also explored extensively the option of in-woods chipping and residue collection. Cooperation with the local USFS is able to offset in large measure the costs of the in-woods operations, which are intrinsically expensive to conduct due to difficulty in maneuvering in the forests, dispersion of wood residues, and poor access for trucks hauling residues to a process facility. Eagle Energy Systems has already negotiated such agreements with the USFS in the St. Maries Ranger District in St. Maries, Idaho.

Currently, common practice is for the purchaser/harvester on a given sale to be required to pile all unmerchantable timber, limbs and tops, and costs of performing this work are paid by the USFS out of the purchase price of the sale. The USFS then has the problem of managing controlled burning of these wastes, costing them a considerable amount of money and resulting in copious quantities of dense gray smoke being released to atmosphere. For these reasons, the USFS is very willing to enter into these kinds of negotiations, and much of the feasibility of the proposed facility depends on the implementation of these agreements. The Wood Residue Utilization Act of 1980, a five year program to be administered by the USFS during the fiscal years 1982-1986, has been established to aid in the effort to make residues from National Forest timber sales available for commercial use. The Act is discussed in greater detail in Section 3 of this report.

Feasibility is also, obviously, dependent equally on the marketability of the manufactured products, densified wood fuel and electricity. Densified wood fuel (pellets) sales are expected to do very well, with perhaps one or two years required to "build up" the market. Already there is considerable interest expressed in the Western Montana area by potential residential, commercial and institutional consumers. Until recently, there has been a great lack of equipment on the market suitable for the efficient utilization of wood pellet fuel, primarily because there has not been a wide-spread, dependable supply of pellet fuel to justify the manufacturing effort. This situation is changing. Equipment has become available in the last few years which will allow a residential consumer with a free-standing airtight stove to economically convert his stove to pellet fuel. Among several incentives to perform this conversion are increasing cost (and lack of supply) of cord wood, greater convenience associated with a refined fuel, and virtual elimination of creosote and smoke formation. Future legislation is also very likely to contribute an incentive to utilize pellet fuel, since many urban areas with air stagnation problems (such as Missoula, Montana), either have enacted or are considering enacting rules limiting the use of cord wood in airtight stoves, due to smoke problems in the atmosphere. Commercial and institutional consumers, typically greenhouses and schools, represent a much larger market than residential due to greater energy requirements. Average consumption for a residence is 5 to 10 tons per year; for greenhouses and schools, consumption is in the range from 600 to 1000 tons per year. As with the residential market, until recently there has not been combustion equipment on the market designed with pellet fuels in mind. In recent months, suspension burners (pellets are pulverised and the fines are burned as they fall through the combustion chamber) have become available in the size range from 2 to 20 MMBTU (millions of British Thermal Units). This size range is that which nearly all commercial and institutional boilers fall into, so that it is now possible to convert gas or oil-fired boilers to wood pellet fuel, often maintaining the option to burn fossil fuels, if desired. Of course, if the commercial or institutional consumer is already using a solid fuel, such as coal, the cost of conversion is greatly reduced since all existing infeed equipment can be retained. Paybacks have been calculated for a number of facilities, typically showing periods of less than a year.

Electricity generated in the proposed facility would be sold to the

Bonneville Power Administration. The Lincoln Electric Coooperative would essentially function to wheel the power into the BPA grid, which would in turn wheel it back to the LEC distribution area. Obviously, this is a hypothetical excursion of electricity from location to location, but this is how the transaction would look on paper. Many of the details of the actual agreement between the LEC and BPA will not be known until such time as the facility goes into construction. There are currently no cogenerators of electricity in the LEC distribution area, and there is only one main power supply route from the BPA grid to the LEC distribution area. The LEC is thus very interested in acquiring some diversity in the supply of their electricity and are eager to cooperate in any way they can to bring this type of project to reality. The LEC policy bulletin on the subject of cogenerator interconnection is Section 4 of this report.

From the viewpoint of facility design, the feasibility of the proposed cogeneration system represents the primary difficulty. The design of the dehydration, grinding, and densifying sub-systems are well proven in past facilities of similar kinds. Based on independent engineering analyses we have had peformed, the technological details of the facility are established as being feasible, and vendor correspondence indicates a high degree of confidence in successful application of currently-available equipment to the design.

# SITING

## 2.1 GENERAL

Much of the data pertaining to project development at a given site will be the same for the entire Eureka area. Items in this category include environmental and construction permits, raw material resource recovery area, species mix and utility interface requirements. For information relative to these subjects for the Eureka area, refer to Sections 3, 4 and 5 of this report. Due to the difficulty in acquiring site information without sincere intent to purchase, a questionnaire format has been developed to aid in compiling such data at a future date. For the purposes of this report, an attempt has been made, through contact with local realtors, to establish a range of cost, both lease and purchase, for industrial zoned acreage in the Eureka area. A site of 10 acres has been assumed. The costs are compiled as follows:

AVERAGE COSTS, 10 ACRES INDUSTRIAL ZONED

Lease (____ YR) ________________________________

Purchase ________________________________

The Site Development Data Form is shown in the following sub-section.

## 2.2 SITE DEVELOPMENT DATA FORM

A. Site Location & Legal Description: ______________________________

______________________________

______________________________

______________________________

______________________________

B. Acquisition Terms and Cost: ______________________________

______________________________

______________________________

______________________________

______________________________

C. Necessary Easements: ______________________________

______________________________

______________________________

______________________________

______________________________

D. Site Access Routes: ______________________________

______________________________

______________________________

______________________________

______________________________

E. Utility Line Proximity/Line Voltage and Capacity: ____________________

F. Land Fill Site Proximity/Cost: ____________________

G. Water Table/Drilling Costs: ____________________

H. Geotechnical Information: ____________________

I. Surface Water Proximity: ____________________

# RAW MATERIAL SUPPLY

## 3.1 GENERAL

The facility's requirements for raw material of 420 tons (50% M.C., wet basis) per day would need to be met by two sources:

- -waste wood recovery methods
- -mill wastes

Waste Wood Collection - This study identified the long-term reliability of in-woods waste wood recovery methods to supply a long-term reliable raw material supply. This is a preference of the financial community, who demand the presence of a consistent, long-term source not affected by industrial cycles associated with mill residues.

The recovery of waste wood in whole log form has been conducted primarily on private lands by and/or for large users of steam and cogenerators, i.e., Champion International of Missoula and Potlatch of Lewiston, Idaho. The recovery process utilizes existing methods of skidding whole trees (dead, diseased and windblown) to a central loading point to be chipped into vans for delivery as "hogged fuel" to the end user. This process is projected by the purchasers of hogged fuel, such as Boise Cascade (Wallula, Washington facility), to become more widespread due to increased demand and subsequent increased cost.

The process is described in the General Accounting Office's Report to the Congress, EMD-81-6, which outlines the tremendous amount of such resource left after a traditional logging contract is completed. The opportunity has attracted companies such as Fuels & Fire Management of Portland, Oregon (see Forest Industries Magazine, October, 1982) who offer a complete timberlands management package to the U.S. Forest Service, State and private land owners and a reliable source of fuel for facilities such as that proposed for Eureka. Major corporations such as Nicholson Manufacturing Company, the manufacturer of the Nicholson wood fuel processor, Howard Cooper Corporation, modifiers of FMC Carriers for waste wood retrieval and collection, and Morbark, manufacturers of high speed chippers, all are proving the viability of in-woods waste wood recovery efforts in select areas.

The Wood Residue Utilization Act of 1980 (see Appendix E) provides the U.S. Forest Service timber sale with credits for biomass treatment work. These credits are allocated through a "Point of Process." Such designation should be sought for the proposed facility. Additional dollars for removal of the residue are provided to offset the costs of transporting waste wood from the woods to a point of process through the Melcher Bill (see Appendix E). These credits are expected to increase the opportunity for loggers to find an alternative marketplace for their efforts. Region I Missoula (the regional office responsible for Eureka) is studying the credit theory through the St. Joe District in Northern Idaho.

One concern often voiced concerning waste wood harvesting for energy is the prospect of a conflict between energy users and the pulp industry. However, as noted in the Thayer School of Engineering - Dartmouth College report, The Forestry and Energy, DSD #157, 8/79, "Mills in the Northwest derive 90% of their pulp supply from their own timberlands. A market for fuel wood will stimulate the development of whole tree harvesting and chipping. Such a development will in turn stimulate those wood products industries that use chips and residue for pulp, reconstituted wood products, and/or chemical derivatives."

Mill Wastes - This resource could provide a substantial percentage of the facility's requirements. However, it cannot be assured of supplying a long-term, reliable quantity to assure a payback of the facility's debt. The primary reasons that inability exists are:

- increased internal demands for steam
- increased internal demands for cogeneration
- cyclical history of the forest products industry

The ever increasing demands on mill wastes are particularly felt in times of reduced sawmill activity. The aforementioned waste wood recovery methods are projected to provide raw material, perhaps at some increased cost (even after application of credits) on a reliable basis. It is, however, expected that mills in numerous locations around the state could provide raw material (although not as reliably) at certain times more cost effectively. This is possible through:

- proximity of the proposed facility to numerous mills in Western Montana and the contiguous areas of British Columbia
- ability of the proposed facility to justify a more competitive posture in hogged fuel acquisition costs when acquired from mills at greater than expected distances when those acquisitions are matched with a backhaul of finished product (economics of distance being dependent on the finished product's end user price).

It was found that mill waste is currently sold almost exclusively to Champion International in Missoula. Being a commodity, the fuel cost is expected to fluctuate according to supply and demand.

Following is a survey of annual estimated quantities of raw material potentially available from mills in the Eureka.

## 3.2 RESOURCE SUMMARY

### Eureka Area

| Source | | |
|---|---|---|
| Kootenai National Forest | | 100,000 tons/yr |
| Letcher Enterprises<br>Roosville, B.C. | | 15,000 tons/yr |
| McDonalds Farms<br>Grasmere, B.C. | | 12,500 tons/yr |
| Galloway Lumber<br>Galloway, B.C. | | 25,000 tons/yr |
| Owens-Hurst<br>Eureka, Montana | | 15,000 tons/yr |
| Ksanka Lumber Co.<br>(Plum Creek)<br>Fortine, Montana | | 12,500 tons/yr |
| | TOTAL | 180,000 tons/yr |

## 3.3 WOOD RESIDUE UTILIZATION ACT OF 1980 - PL 96-554 (WRUA)

The Wood Residue Utilization Act of 1980, PL 96-554 (WRUA) authorizes the Secretary of Agriculture to establish pilot projects and demonstrations to increase the utilization of wood residue. The act will be carried out under the Special Wood Residue Utilization Program (RUP) administered by the Forest Service. RUP is a five-year program for fiscal years 1982-1986.

This special program has three main parts: (1) projects and demonstrations to increase and improve the utilization of wood residues from public and private lands in general, (2) projects for the utilization of residues under National Forest timber sale contracts, and (3) making information available on feasible methods with potential for commercial application to increase and improve residue utilization.

RUP activities are aimed at using residues resulting from timber harvesting, forest protection, and forest management activities occurring on public and private lands and from the manufacture of forest products, including wood pulp.

RUP crosses the three Deputy areas of the Forest Service-the National Forest System, State and Private Forestry, and Research. See FSM 2439 for a discussion of the overall program, the responsibilities of the three major Forest Service areas, and for details relating to residue utilization under National Forest system timber sales. See FSM (Forest Service Manual) 3242.22e for State and private Forestry responsibilities for projects on private and public lands other than National Forest System lands and FSM 4021.2 for research responsibilities in RUP. This information may be acquired either at a local U.S.F.S. office, or by addressing a request to:

United States Forest Service
ATTN: Deputy Regional Forester, Administration
319 S.W. Pine St.
P.O. Box 3623
Portland, Oregon 97208

# PERMITS AND ENVIRONMENTAL

## 4.1 GENERAL

The permits required for the proposed densification/cogeneration facility are the same for any of the potential sites in the Eureka area. First, a permit to construct an air polluting facility must be applied for, since significant quantities of particulate material, as well as some hydrocarbons (or "blue haze") are emitted from the facility in normal operation. Second, a plan review application must be submitted to obtain the necessary building permit, which in turn requires subcontractors (in the construction term) to submit permit applications for septic systems, electrical, plumbing and HVAC (heating, ventilation and air conditioning). Since no water of significant quantity is either used or discharged, the State of Montana Water Quality Bureau has stated that a permit to discharge water from the facility will not be required. Likewise, because there are no toxic or hazardous wastes emitted or discharged, special permits of this kind will also not be required.

The Plan Review Application (for building permit) is processed by the State Department of Administration, Building Codes Division. The Air Quality Permit Application is processed by the State Department of Health and Environmental Sciences, Air Quality Bureau. The application forms for these permits are included in Appendix D.

## 4.2 AIR QUALITY

The permits related to ambient air quality are the most complex and time consuming of all permits required for the facility. This is because there are several review processes which the facility may be subject to, some of which are administered by the State, and some by the federal government (EPA). For the proposed facility, the air quality permit could involve the PSD (Prevention of Significant Deterioration) and NSPS (New Source Performance Standards) reviews. The PSD review is currently administered by the EPA and the NSPS review is conducted by the State. Both review processes originated in the federal Clean Air Act and have been adopted by the State in the Montana Clean Air Act. The State of Montana anticipates having promulgated authority to conduct the PSD review by the end of 1983.

The purpose of the PSD regulations is to protect the ambient air quality from "significant deterioration" caused by new sources. For the purposes of PSD evaluation, the ambient air quality is divided into three classes in the State with Class 1 being most carefully protected category (ie., allowing the smallest increase in ambient contaminant levels), Class 2 allowing moderate increases in contaminant levels, and Class 3 the category allowing the largest increase in ambient contaminant concentrations. In order to make a PSD evaluation it is necessary to have defined the Baseline Concentrations of all regulated contaminants in the ambient air. It is then necessary to evaluate the expected increase in these concentrations of contaminants caused by operation of the proposed facility. Limitations are placed on the value of this increase in contaminant concentration, based on which of the PSD classes the proposed site falls into. Under the Air Rules of Montana (ARM), ARM 16.8.902 and 16.8.906, all of Montana is classified as either Class 1 or Class 2. The Class 1 areas nearest to Eureka are Glacier National Park, 30 miles East, the Cabinet Wilderness Area, 45 miles Southwest, and the Flathead Indian Reservation, 70 miles South. Although the full effects are not known at this time, it is expected that no significant impact on these areas would result from operation of the proposed facility. The Eureka area itself falls into Class 2. The following table summarizes the applicable PSD regulations for Classes 1 and 2:

PSD REGULATIONS

| Contaminant | Maximum allowable increase (micrograms per cubic meter) |
|---|---|
| **Class 1** | |
| Particulate matter: | |
| Annual geometric mean | 5 |
| 24-hr maximum | 10 |
| **Class 2** | |
| Particulate matter: | |
| Annual geometric mean | 19 |
| 24-hr maximum | 37 |

Of all regulated contaminants, only particulate and hydrocarbons are of concern for the proposed facility. The production of oxides of sulfur is very low due to extremely low sulfur content in wood fuels, and oxides of nitrogen (formation rates of which are temperature dependent) are limited by the relatively low combustion temperatures involved in the facility processes. Applicability of PSD review is thus based primarily on expected emissions of particulate from the facility. For certain types of new sources (listed in ARM sub-chapter 8), a facility which has the "potential to emit" more than 100 tons per year of any regulated pollutant is classified as a Major Stationary Source and is subject to PSD review. Even if not listed in ARM sub-chapter 8, a facility which has the potential to emit more than 250 tons per year of any regulated pollutant is also classified as a Major Stationary Source and thus is subject to PSD review. Potential to emit is defined in ARM sub-chapter 8 as being the maximum emission rate with pollution control equipment in place. The expected rate of particulate emission for the proposed facility is approximately 175 to 250 tons; it is thus possible that a PSD review may not be required.

The proposed facility will probably require a NSPS review, since the cogeneration system includes a stationary gas turbine, which is a named category of new sources requiring review (ARM 16.8.1423). As mentioned previously, the State of Montana has promulgated authority to conduct NSPS reviews.

In addition to the above reviews, the proposed facility is subject to emissions rate limitations set forth in ARM 16.8.1401-5. These limitations are based on either the quantity of fuel (heat) input to fuel burning equipment, or, if a combustion process is not involved, on the weight rate of any emissions related process. For the proposed facility, the fuel burning rate limitation will apply to the cogeneration system burner: for a heat input of 48 million BTUS per hour, ARM 16.8.1402 specifies a maximum allowable particulate emission rate of 16.8 pounds per hour. For the several grinding and conveying processes in the proposed facility, the following equation is used to determine the maximum allowable particulate emissions (ARM 16.8.1403):

$$E = (4.10xP)\uparrow(0.67)$$

Vendor quotations indicate that these emissions rates are achievable using standard high-efficiency cyclones and multi-cyclones.

## 4.3 NOISE

Another environmental consideration in the proposed facility is the level of noise generated by vehicles coming and going at the site, process equipment, and the cogeneration system equipment. The proposed project will generate noise levels similar to or lower than lumber mill activities. Essentially, the noise impacts of the proposed project can be broken into two components--operation of plant equipment and operation of motor vehicles. The plant operation will consist of the following activities: grinding of wood residues (raw material), combustion, power generation, and dehydration. The most noise intensive of these operations will be the operation of the generator (gas turbine) and the grinders. The noise levels generated by these operations will be roughly equivalent. The combustion and dehydration functions will be 8 to 10 dBA lower in noise intensity than the turbine or grinder. The unshrouded noise levels generated by the turbine are projected at 66 to 86 dBA at 50 feet (manufacturer's specifications). All of this equipment will be housed in a concrete block structure and will be designed to meet federal noise guidelines. It is estimated that the structure will provide up to 35 dBA in noise reduction (based on interpolation of data from Wyle Research Report WCR 75-2, Community Noise Countermeasures Cost-Effectiveness Analysis, Wyle Laboratories, 1975). With the noise reduction provided by the structure, outdoor levels from the plant operations are projected to be 51 dBA at a distance of 50 feet. It should be noted that there may be noise leaks from the grinding operations as a result of loading wood materials. The plant will be located approximately 300 feet from the site boundary. With a noise reduction of 5 dBA for each doubling of distance from the source to the observer, the estimated level received at a distance of 450 feet will be less than 40 dBA. Forklift and loader operations will generate noise levels of about 80 dBA.

# UTILITY INTERCONNECTION

## 5.1 LINCOLN ELECTRIC COOPERATIVE, INC.
## POLICY BULLETIN NO. 503

Subject: Interconnection and operation of alternate electric energy generating systems.

Objective: To provide guidelines on the purchase of electricity from, and the interconnection of small power generation and alternate energy systems.

General: To help alleviate the Nation's proclaimed shortage of electric energy, the Cooperative will work with its member-consumers and others to encourage the interconnection of alternate electric supply systems to the Cooperative's low voltage system. In addition to electricity, much useful information can and should be generated for the benefit of the generating system owner, other member-consumers and the Cooperative.

The requirements and conditions which follow are for connected consumer-owned generation facilities rated at less than the owner's distribution transformer capacity, to a maximum of 50 KW. Generators with ratings higher than the owner's transformer capacity, and all generators rated at more than 50 KW will be handled on an individual basis.

Positive safeguards from electric shock and other hazards are essential and must be provided to protect the generating system owner, the general public and the Cooperative's line personnel. These safeguards can and must be provided by using stringent safety rules and practices.

Policy: The following conditions and requirements are to be fulfilled before a consumer owned electric generating system can be interconnected to the Cooperative's electrical distribution system:

1. Any member-consumer or other entity who wants to install a generating system on their premises, and wants to interconnect it with the Cooperative's distribution system must notify the Cooperative prior to the interconnection.

2. A written offer or proposal to sell electricity to the Cooperative must be submitted along with detailed diagrams of the generator and related equipment. These diagrams must show all related wiring and safety features of the generating system.

3. The Cooperative and the generator owner must comply with all applicable provisions of the State Electrical Code and the National Electric Safety Code.

4. The consumer's generating system, including interconnecting equipment, shall meet the requirements of and be inspected and approved by the State Electrical Inspector and any other public authority having jurisdiction before any interconnection is made to the electric system of the consumer or the Cooperative.

5. Wind driven generating facilities, for safety purposes, shall be connected by underground conductor in conduit of a horizontal length not less than 1.5 times the fall distance of the generating facility from the Cooperative facility(s).

6. Monthly minimum charge shall be applied as outlined in Rate Schedule "A" for electric energy required by the generating system.

7. To protect appliances and equipment on the premises of the generator owner and other consumers, the power generated by the member shall not induce excessive distortion to the system's voltage or current sine waves. The maximum allowable distortion must not exceed 10% measured at the consumer's service box.

8. If the generating system interferes with the operation of Cooperative equipment or interferes with other member services, the Cooperative reserves the right to disconnect.

9. The consumer's (generating owner's) load, in conjunction with the generating system shall not have a power factor of less than .95.

10. To protect the generating system, and to protect all parties from electric shock, the generator system owner shall supply and install an automatic circuit breaker to positively disconnect his generating equipment from the system in the event of a disturbance or supply outage on the Cooperative's system. The Cooperative shall be allowed access to this device at all times to permit periodic safety tests.

11. The generator owner shall furnish and install a disconnecting switch to be connected between the Cooperative's electric system and the generating system. This switch must provide a visual opening in the line and shall be located and equipped so that Cooperative personnel can operate and lock the switch in case of an outage or for work on the distribution system.

12. The member shall furnish and install all additional wiring and equipment needed to connect the generating system metering at existing service location. The meter socket shall be installed as close as possible to the existing service meter.

13. The Cooperative will furnish and maintain two meters for the generating system. One meter will measure flows of power and energy from the generating system into the Cooperative's electric system. The other meter will measure flows to the generating system for consumption by the generating system's auxiliary equipment during start up, or other times when the generator is idle or non-producing.

    The above described two meters will be in addition to the regular meter serving the home or other premises of the member-consumer generator owner.

14. The Cooperative will purchase energy (kwh) recorded on the meter or meters serving the generating system at a rate equal to its

"avoided cost" which is deemed to be the net rate the Cooperative would have paid its wholesale power supplier for the kilowatt hours.

The Cooperative will also purchase capacity (demand kwh) from generating systems that can schedule and guarantee firm delivery during the Cooperative's various peak use periods. Payment, therefore, will be at a rate not greater than the Cooperative's "avoided cost" for demand KW (capacity) which is deemed to be the net rate the Cooperative would have paid its wholesale power supplier.

15. The generating system owner-operator's written offer must include a statement which will indemnify and hold the Cooperative harmless from any and all liabilities arising from the operation and interconnection of the generating system.

Responsibility: The Manager shall be responsible for carrying out the provisions of this policy, and may delegate certain responsibilities to staff members or consultants of the Cooperative.

Procedure: As outlined above.

# FACILITY CONFIGURATION

## 6.1 GENERAL

As per the grant document contracts, the following is a summary of the preliminary design of a 240 ton per day wood residue densification facility with 2.0 MW cogeneration capacity. The material presented describes the facility verbally, as well as with drawings, diagrams, and equipment specifications. The descriptive Section 6.3 also includes much of the preliminary design parameters of the cogeneration system, and Section 6.4 summarizes the results of an independent engineering feasibility study of the Indirectly Heated Gas Turbine configuration in our cogeneration mode. Section 6.5 describes a computer program designed to predict performance of the system as designed in this report for varying input parameters (elevation above sea level, EASL; turbine inlet temperature, TIT; ambient temperature, TAMS). The Jaycor study is located in Appendix D; the computer program code is in Appendix A.

## 6.2 PROCESS FACILITY DESCRIPTION

### Raw Material Handling

Raw Material will be brought to the site by truck and trailer from collection points. Collection points will be mill sites and in-woods operations in the area. Material will be unloaded by hydraulic deck-type trailer dumper, 33 ft. in length, with a 50 ton capacity (Reference # N-002). The trailers, when dumped, will empty onto a deck to be moved by front-loader onto the infeed drag chain (N-004). A covered belt conveyor (N-006) with a permanent magnet (for removal of tramp metal) will convey material from the drag chain to a vibrating screen classifier (N-008). The overs from the vibrating screen enter the primary grinder, a large hammer "hog" (N-010).

After primary grinding, the infeed material will be sized 1" and smaller; this material will be joined at this point by the unders from the vibrating screen (also 1" and smaller). The sized material is then conveyed to a infeed surge bin (N-014) by a belt conveyor (N-012).

### Dehydration Process

The infeed surge bin will be equipped with a metering screw bottom conveyor (N-016) which will meter material out of the bin; this screw conveyor will be equipped with variable speed drive for control of flow rate. Material will be fed from the metering screw to dryer inlet by a horizontal screw conveyor (N-018) operating at constant speed. At the dryer inlet, material will fall into the drying media (hot gases from the cogeneration system) through a rotary airlock feeder. The rotary-drum dryer (D-002) will mix the hot gases and wet wood material allowing time for evaporation to take place. At the exit of the dryer, dehydrated material will be conveyed by the hot air stream into a large centrifugal collector or "cyclone" (D-004); the hot gases, being pulled by a large fan (D-008) through dryer and cyclone, will then be exhausted through a "multi-cyclone" type secondary dust collection system (D-006) before being discharged to atmosphere. See page 6-7 for process diagrams and mass flows.

## Dried Material Processing

The dried material collected by the dryer cyclone will exit the cyclone via a rotary airlock and screw conveyor (D-010), and enter a reel scalper (G-002), designed to separate 3/16" minus material from the process flow. The separated 3/16" minus material will be conveyed by a material conveying fan to a centrifugal collector (G-012), which will discharge collected material via a rotary airlock into the processed material metering bin (G-022). Metering augers will feed material from the bin to the pellet mills and the cogeneration fuel conveying fan at prescribed rates of flow.

The bulk of the material from the reel scalper (greater than 3/16" in size) will be conveyed from the reel scalper to the hammermill metering bin (G-006) via an inclined screw conveyor (G-004). Material will then be fed uniformly to the hammermills by metering screws (G-010). The hammermills (G-008) will be equipped with 3/16" screens, so that grinding to 3/16" minus is accomplished. Both hammermills will be mounted on air bases to allow air conveying of ground material: air conveying ducts transport material to centrifugal collectors (G-014), which will in turn discharge collected material into the processed material metering bin via rotary airlock feeders. See page 6-8 for process diagrams and mass flows.

## Cogeneration System

From the processed material metering bin, material will be conveyed by a metering screw (G-018) and fuel conveying fan (G-016) to a centrifugal collector (C-004). Material will then be fed by a metering screw into the fuel hammermill (C-006), where it will be reduced to 1/16" minus size. A fan (C-008) will convey the pulverised fuel from the hammermill to the cyclonic burner (C-010). The combustion air requirements of the burner will be met by the fuel conveying air and the hot, clean air being returned from the turbine exhaust. Downstream from the burner, the high temperature combustion products travel through the shell side of the heat exchanger (C-012), giving up approximately 50% of their sensible heat on the compressed air stream flowing on the tube side of the heat exchanger, between the compressor and turbine stages of the turbine engine (C-014). The exhaust gases exiting the heat exchanger will then enter the dryer to join the wet infeed material. See page 6-8 for process diagrams and mass flows.

## Densification Process

From the processed material metering bin (G-022), material will be conveyed by two metering screws (G-026) to the pellet mills (P-008). The formed pellets will then be transferred by a belt conveyor (P-010) to the pellet cooler (P-012). In the cooler, ambient air is drawn through the hot pellets by the pellet cooler fan (P-004) and conveyed (along with some vapor and fines) to the pellet cooler collector (P-006), a centrifugal cyclone. The dust collected by the cooler cyclone will be discharged through a rotary airlock into the process material metering bin for recycling. The cooled pellets will exit the cooler and enter a rotary-type flat screen (P-014) for fines and crumbles removal. The fines and crumbles will be conveyed to the boiler fuel feed bin (P-016) for use as fuel (this fuel will be supplemented with pellets as necessary). Whole pellets will exit the screen and will be conveyed via a bucket elevator (S-002) and belt conveyor (S-008) to either the truck loading bin (S-004) or product storage bin (S-012).

During truck loading, material may be fed back to the truck loading bin from product storage by means of a sweep-type live bottom screw auger (S-010) and bucket elevator (S-006). Directly below the truck loading bin will be a set of scales with electronic digital readout and slip printing (S-014). See page 6-9 for process diagrams and mass flows.

# RAW MATERIAL PROCESSING

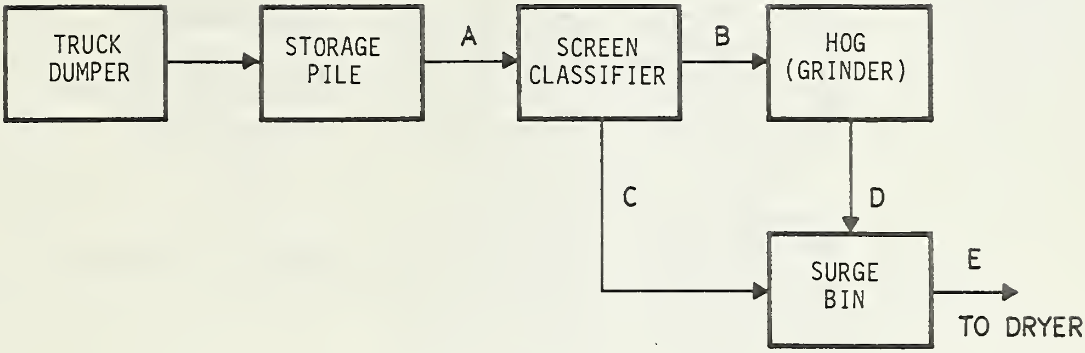


FIG. 1

| STATION | UNITS | A | B | C | D | E |
|---|---|---|---|---|---|---|
| MATERIAL | TYPE | WOOD | WOOD | WOOD | WOOD | WOOD |
| MASS FLOW | TON/HR | 21 | 14 | 7 | 14 | 21 |
| | LB/HR | | | | | |
| MATERIAL SIZE | IN. − | 4 | 4 | 1 | 1 | 1 |
| | IN. + | | 1 | | | |
| MOISTURE | % W.B. | 45 | 45 | 45 | 45 | 45 |
| TEMP. | °F | 40 | 40 | 40 | 90 | 60 |

TABLE 1

# DEHYDRATION PROCESS

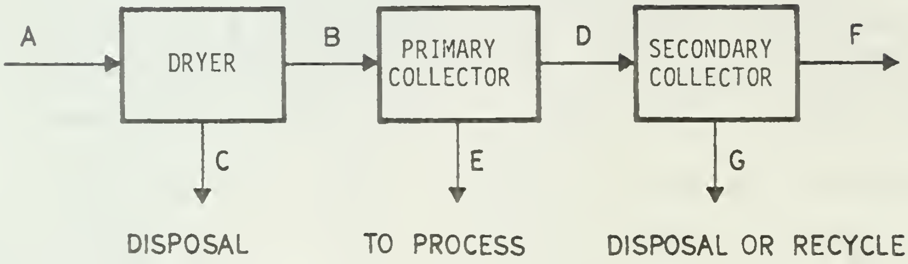


FIG. 2

| STATION | UNITS | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|---|
| MATERIAL | TYPE | WOOD | WOOD | ROCK | DUST | WOOD | DUST | DUST |
| MASS FLOW | TON/HR | 21 | 12 | | | 13.9 | | |
| | LB/HR | | | 100 | 120 | | 1.2 | 118.8 |
| MATERIAL SIZE | IN. − | 1 | 1 | -- | -- | 1 | -- | -- |
| | IN. + | | | | | | | |
| MOISTURE | % W.B. | 45 | 16 | -- | -- | 16 | -- | -- |
| TEMP. | °F | 60 | 225 | 225 | 200 | 200 | 175 | 175 |

TABLE 2

# DRIED MATERIAL PROCESSING

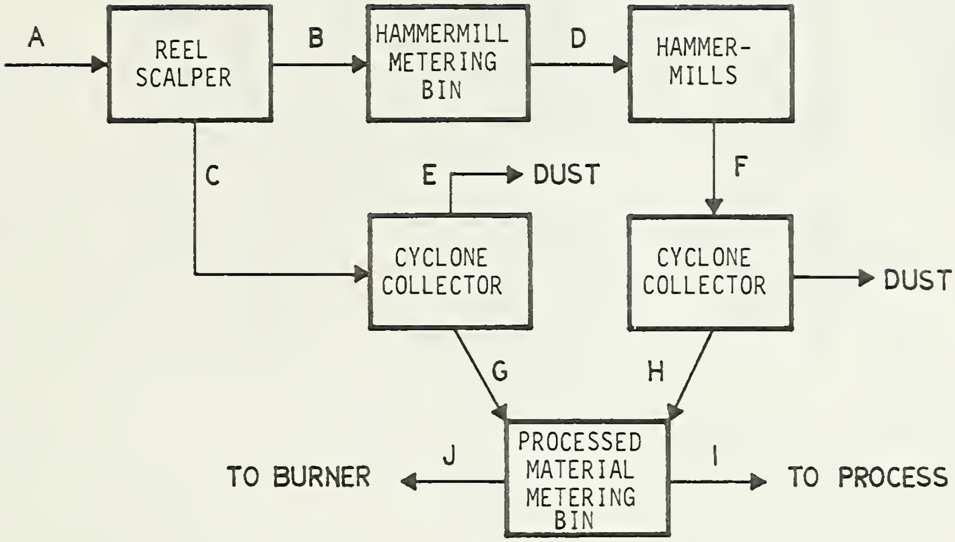


FIG 3

| STATION | UNITS | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MATERIAL | TYPE | WOOD | WOOD | AIR/WOOD | WOOD | DUST | AIR/WOOD | WOOD | WOOD | WOOD | WOOD |
| MASS FLOW | TON/HR | 13.9 | 9.0 | 4.9 | 9.0 | -- | 9.0 | 4.9 | 9.0 | 10.9 | 3.0 |
| | LB/HR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| MATERIAL SIZE | IN. − | 1 | 1 | 3/16 | 1 | -- | 3/16 | 3/16 | 3/16 | 3/16 | 3/16 |
| | IN. + | -- | 3/16 | -- | 3/16 | -- | -- | -- | -- | -- | -- |
| MOISTURE | % W.B. | 16 | 16 | 15 | 15 | -- | 15 | 15 | 15 | 15 | 15 |
| TEMP. | °F | 100 | 90 | 90 | 80 | -- | 120 | 80 | 80 | 80 | 80 |

TABLE 3

## DENSIFICATION PROCESS

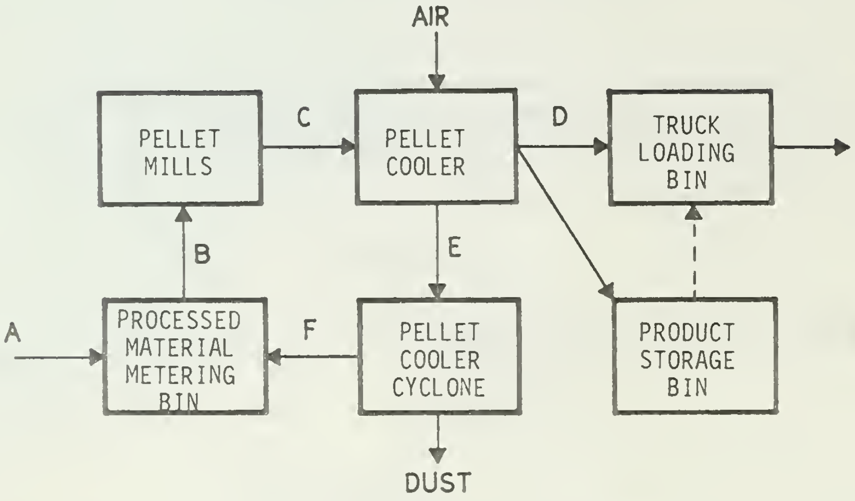
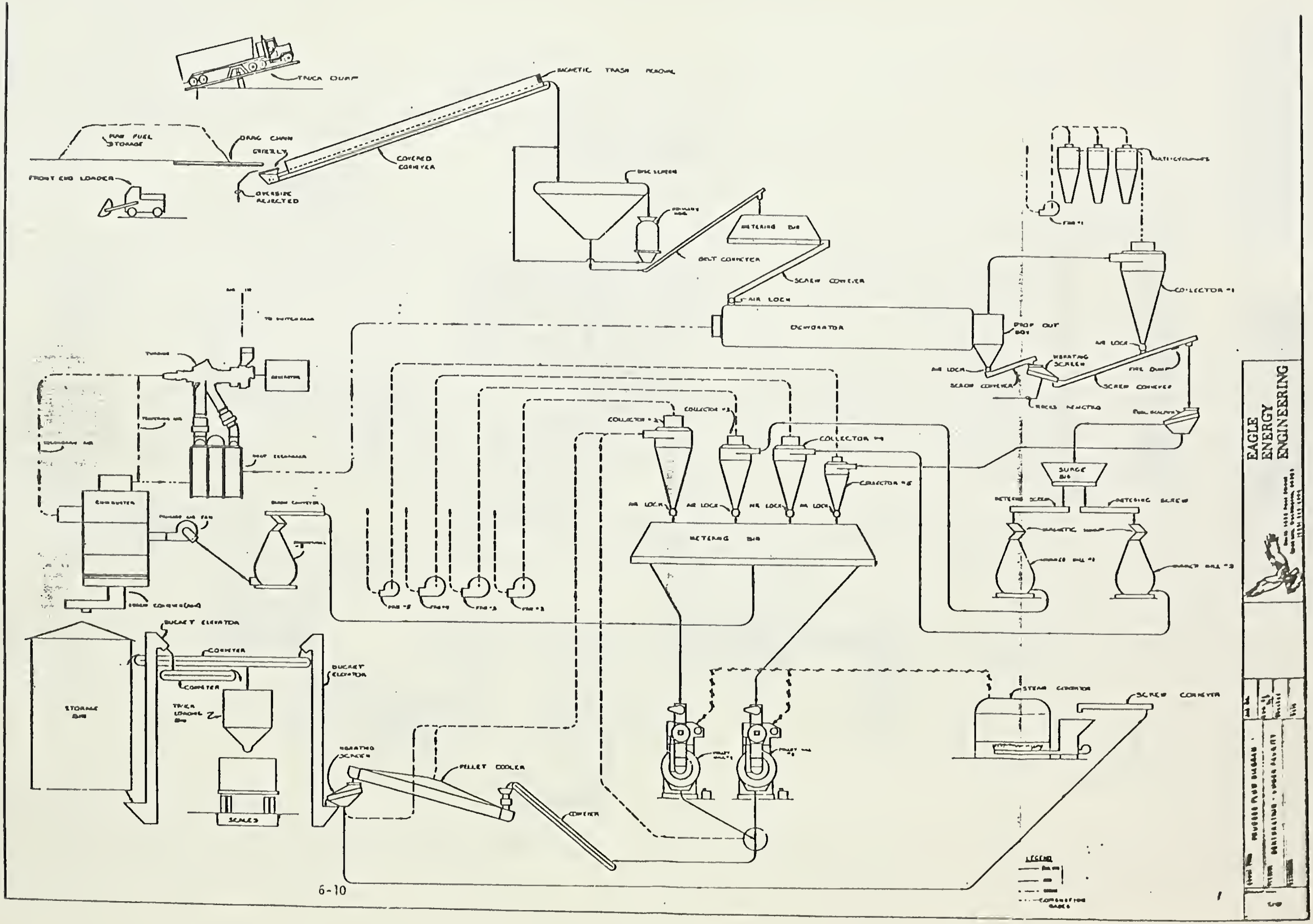
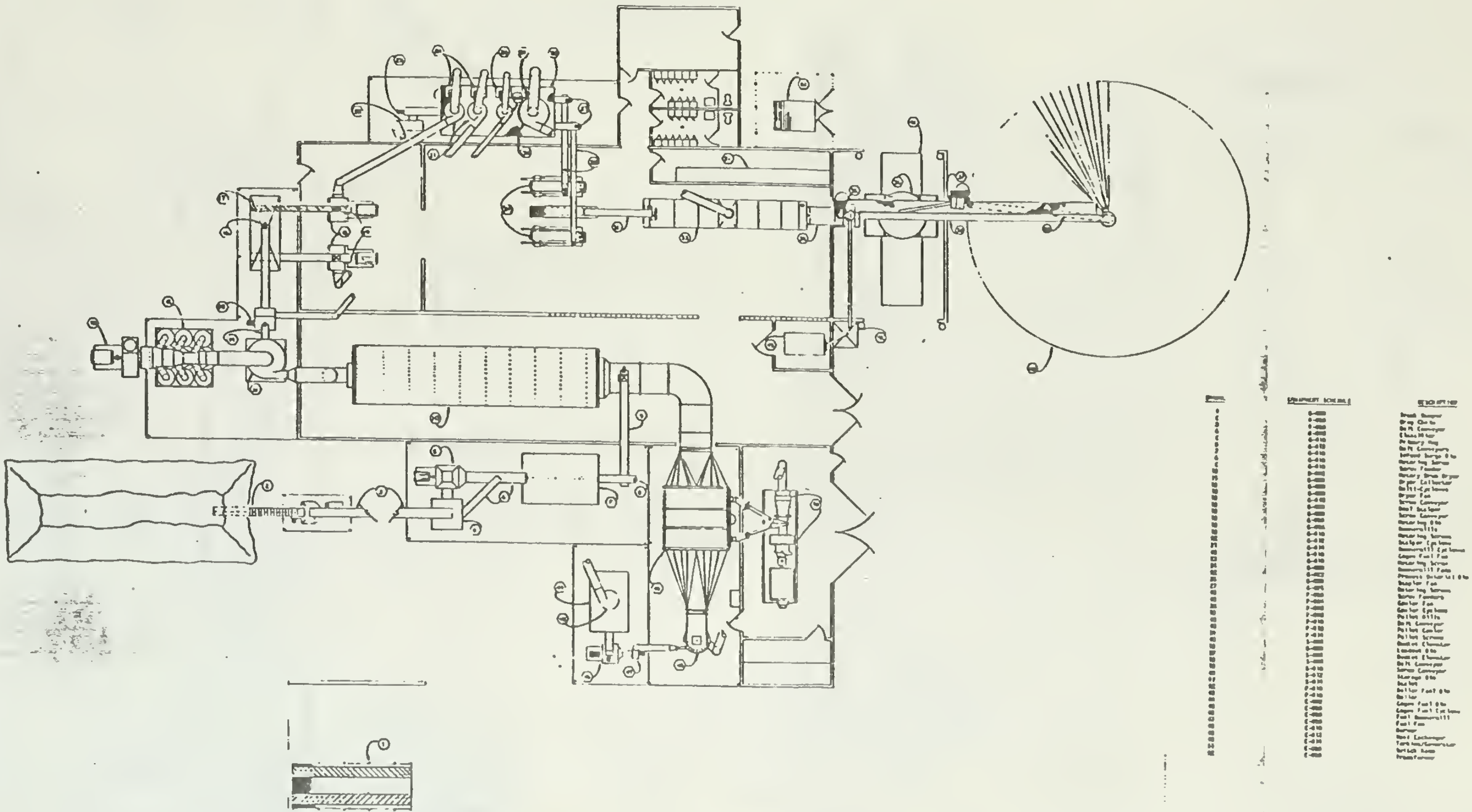


FIG 4

| STATION | UNITS | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|---|
| MATERIAL | TYPE | WOOD | WOOD | PELLET | PELLET | AIR/ FINES | FINES | STEAM |
| MASS FLOW | TON/HR | 10.9 | 11.0 | 11.0 | 10.9 | 0.1 | 0.1 | -- |
| | LB/HR | -- | -- | -- | -- | -- | -- | 850 |
| MATERIAL SIZE | IN. − | 3/16 | 3/16 | 1/4 | 1/4 | -- | -- | -- |
| | IN. + | -- | -- | -- | -- | -- | -- | -- |
| MOISTURE | % W.B. | 15 | 15 | 15 | 14 | -- | -- | SAT |
| TEMP. | °F | 80 | 80 | 250 | 90 | -- | -- | 300 |

TABLE 4


TRUCK DUMP
MAGNETIC TRASH REMOVAL
RAW FUEL STORAGE
DRAG CHAIN
GRIZZLY
COVERED CONVEYOR
FRONT END LOADER
OVERSIZE REJECTED
DISC SCREEN
PRIMARY HOG
METERING BIN
BELT CONVEYOR
SCREW CONVEYOR
MULTI-CYCLONES
FAN #1
COLLECTOR #1
AIR LOCK
DEHYDRATOR
DROP OUT BOX
AIR LOCK
VIBRATING SCREEN
FIRE DUMP
SCREW CONVEYOR
SCREW CONVEYOR
ROCKS REJECTED
TO SWITCHGEAR
TURBINE
GENERATOR
TEMPERING AIR
SECONDARY AIR
HEAT EXCHANGER
COMBUSTOR
PRIMARY AIR FAN
BURNER CONVEYOR
ASH CONVEYOR
COLLECTOR #2
COLLECTOR #3
COLLECTOR #4
COLLECTOR #5
AIR LOCK
AIR LOCK
AIR LOCK
AIR LOCK
METERING BIN
FAN #5
FAN #4
FAN #3
FAN #2
SURGE BIN
METERING SCREW
METERING SCREW
MAGNETIC HUMP
HAMMER MILL #1
HAMMER MILL #2
BUCKET ELEVATOR
CONVEYOR
BUCKET ELEVATOR
CONVEYOR
STORAGE BIN
TRUCK LOADING BIN
SCALES
STEAM GENERATOR
SCREW CONVEYOR
VIBRATING SCREEN
PELLET COOLER
PELLET MILL #1
PELLET MILL #2
CONVEYOR
LEGEND
COMBUSTION GASES
EAGLE
ENERGY
ENGINEERING
PROCESS FLOW DIAGRAM

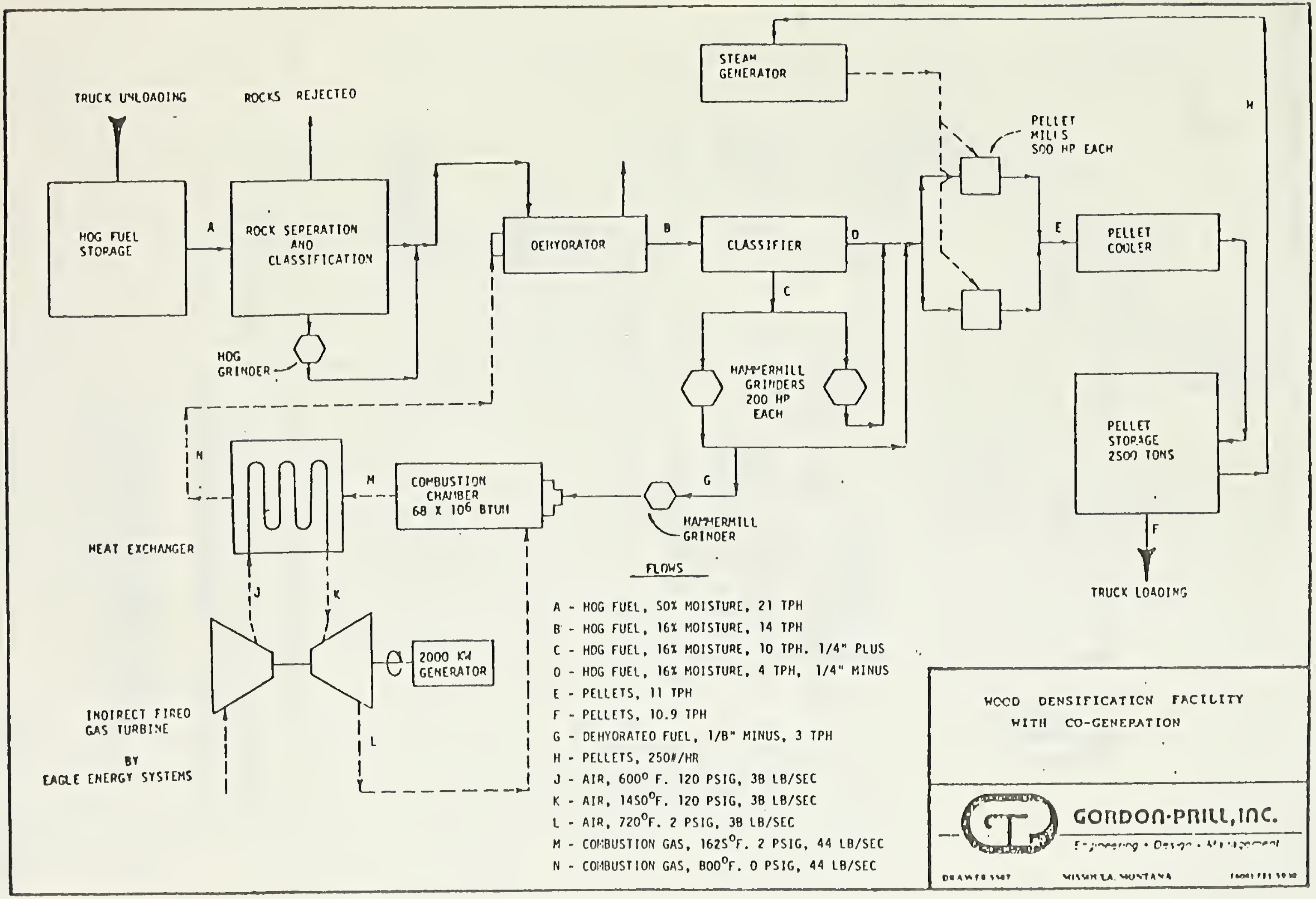


## EQUIPMENT LAYOUT

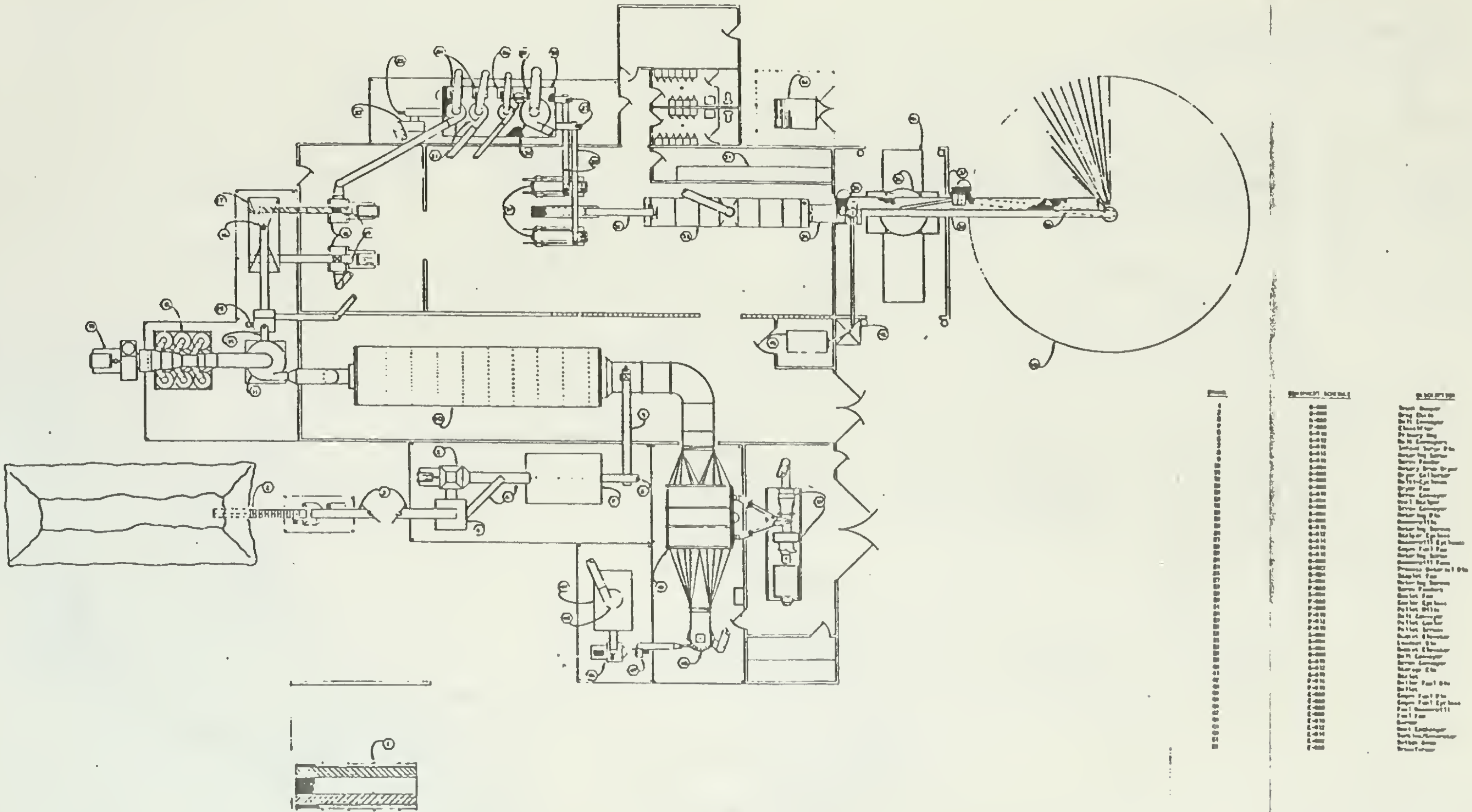
SCALE 1/8"=1'-0"

**EAGLE ENERGY ENGINEERING**

Sheet Title: PLANT LAYOUT
Project: DEHYDRATION - COGEN FACILITY
Revisions
Job No.
Dwn. By BJ
Checked
Date
Sheet No. 8/8


TRUCK UNLOADING
ROCKS REJECTED
HOG FUEL STORAGE
A
ROCK SEPERATION AND CLASSIFICATION
HOG GRINDER
DEHYORATOR
B
CLASSIFIER
C
D
HAMMERMILL GRINDERS 200 HP EACH
STEAM GENERATOR
PELLET MILLS 500 HP EACH
E
PELLET COOLER
H
PELLET STORAGE 2500 TONS
F
TRUCK LOADING
N
HEAT EXCHANGER
M
COMBUSTION CHAMBER 68 X 10⁶ BTUH
G
HAMMERMILL GRINDER
J
K
L
2000 KW GENERATOR
INDIRECT FIRED GAS TURBINE
BY
EAGLE ENERGY SYSTEMS
FLOWS
A - HOG FUEL, 50% MOISTURE, 21 TPH
B - HOG FUEL, 16% MOISTURE, 14 TPH
C - HOG FUEL, 16% MOISTURE, 10 TPH. 1/4" PLUS
D - HOG FUEL, 16% MOISTURE, 4 TPH, 1/4" MINUS
E - PELLETS, 11 TPH
F - PELLETS, 10.9 TPH
G - DEHYORATED FUEL, 1/8" MINUS, 3 TPH
H - PELLETS, 250#/HR
J - AIR, 600° F. 120 PSIG, 38 LB/SEC
K - AIR, 1450°F. 120 PSIG, 38 LB/SEC
L - AIR, 720°F. 2 PSIG, 38 LB/SEC
M - COMBUSTION GAS, 1625°F. 2 PSIG, 44 LB/SEC
N - COMBUSTION GAS, 800°F. 0 PSIG, 44 LB/SEC
WOOD DENSIFICATION FACILITY
WITH CO-GENERATION
GORDON-PRILL, INC.
Engineering • Design • Management
MISSOULA, MONTANA

EAGLE ENERGY SYSTEMS



EQUIPMENT LAYOUT

SCALE 1/8"=1'-0"

| | | | |
|---|---|---|---|
| 8/8 | Sheet Title | PLANT LAYOUT | Job No. |
| | Project | DEHYDRATION - COGEN FACILITY | Drn. By SJ |
| | Revisions | | Checked |
| | | | Date |

EAGLE
ENERGY
ENGINEERING

[illegible]

## 6.3 COGENERATION SYSTEM

### Gas Turbine

#### Scope

The gas turbine, generator, and controls shall be Solar Turbines, Inc., Centaur Engine, skid mounted, as outlined below.

### Indirectly Heated Gas Turbine Option

#### General Description

The gas turbine or Brayton cycle offers many advantages over a conventional power plant, expecially when installed in a cogeneration mode. These advantages include physically compact packages, high reliability, improved system economics and full operating flexibility to meet variable electrical/steam demand. Until the introduction of the EES indirectly heated option for the Centaur generator set, the primary disadvantage of the gas turbine cycle has been that internal burning of alternate fuels caused unacceptable erosion and corrosion of turbine blading. The indirectly heated gas turbine combines the operating flexibility and system economics advantages of the standard gas turbine cycle with the practical necessity of using available alternative fuels.

A comparision of the available gas turbine cycle arrangements is shown in Figure 1. The simple cycle arrangement is the standard gas turbine generator set. Ambient air is compressed in an axial flow compressor. Fuel is continuously added and burned in a combustor. The hot combustion gases pass through the turbine to produce power. The recuperated cycle arrangement is the recuperated version of the simple cycle gas turbine.

Hot exhaust gases are directed through a heat exchanger, and raise the temperature of the compressor or discharge air before combustion in an external combustor.

The indirectly heated arrangement uses the experience and the design knowledge gained on the recuperated engine program to produce an indirectly heated option for the Centaur generator set. In the indirectly heated gas turbine cycle, the compressor and turbine of the simple cycle turbine are retained but the necessary heat addition is achieved by passing the compressed air through a heat exchanger rather than directly burning the fuel in the air stream. Only clean air passes through the turbine. Figure 2 is a preliminary layout drawing of an indirectly heated Centaur generator set.

The Solar Centaur industrial gas turbine engine is designed for long life and maintenance. One of the foremost design requirements is that the turbine operated at conservative gas temperatures and stress levels to ensure long life of the major components.

## Indirectly Heated Gas Turbine Performance

The following are the design basis for the indirectly heated Centaur generator set.

Ambient Temperature 59 degrees F.
Turbine Inlet Temperature 1450 degrees F.
Compressor Discharge Temperature 595 degrees F.
Compressor Pressure Ratio 9.1:1
Mass Flow lb/sec 38.4

Exhaust Temperature 700 degrees F.

Elevation Sea Level, No Inlet or Exhaust Losses

External Pressure Drop of 7.5 PSI

Based on these design conditions, the indirectly heated Centaur will produce a nominal 2000 KW at the generator terminals.

Figures 4 and 5 (see pages 6-35, 36) are power output correction curves for elevation and inlet and outlet losses and are to be applied to the nominal performance point to determine the actual output of the generator. These corrections can be applied only after the exact system configuration has been defined.

### Control System Design Philosophy

The objectives of the control system are twofold, first, to satisfy the electrical demand placed on the system; and second, to ensure that each gas turbine component stays within acceptable operating limits. To satisfy the latter requirements, the control system design will include provisions for emergency load reduction as well as provisions for handling all normally expected operating loads and large load transients which the system may impose on the generating unit.

The gas turbine performance is controlled by the shaft speed and the turbine inlet gas temperature. The control valves located in the air lines between the gas turbine and the heat exchanger modulate via signals originating from the control panel. After the turbine speed is synchronized to the utility grid frequency the turbine speed is fixed. By control of the turbine inlet temperature the gas turbine electrical output is selected.

The gas turbine control system will interface with the combustion control system during startup and load changes. EES's control system will interface as necessary with the plant control system to ensure a coordinated response to all external disturbances placed on the system.

## Centaur Generator Set Package Description

### Basic Set

Indirectly Heated Solar Centaur gas turbine generator set as described in Solar publication T56B with modifications for a high efficiency heat exchanger in place of the standard gas fueled combustion system. Package rating for continuous duty is 2000 KW at 59 degrees F, sea level, with no inlet or exhaust losses. Features included in this proposal are as follows:

Engine - The Centaur industrial gas turbine is a single-shaft engine in which the gas producer and power turbine are integrally designed. The accessory gearbox is a close coupled unit located at the inlet end of the engine. The engine is the recuperated version, with discharge and inlet parts replacing the normally included combustion system.

Gearbox - 1800 RPM - A speed reducing gearbox capable of reduction to 1800 RPM for 60 Hertz generator. A flexible, shear coupling connects the output shaft of the gearbox to the generator shaft.

Generator - Volts, 60 Hertz - The generator rated output is Volts, 60 Hertz, three-phase, six-lead, standard performance.

Start System - Electric/Hydraulic, 230/460 Vac, 3-phase, 60 Hertz. The system consisted of a motor-driver, positive displacement pump, and an accessory gearbox-mounted hydraulic motor/starter assembly. Hydraulic oil is provided from package oil system. The start system is sized to provide a starting sequence of up to 30 minutes. The required motor starter is not included.

Lube Oil System - Consists of an on-skid duplex multi-element filter system including changeover valves and a warning signal when filter changeout is required.

Lube Oil Vent Separator - A coalescer element is included on the package to remove oil from the lube oil tank vent.

Control Console - A free standing unit containing all controls and circuitry necessary for turbine operation and protection. Designed for mounting in a nonhazardous area. See section entitled "Control Philosophy" for more detail information on the control system. All AC transformers required for governor and control system operation are not included. Control system components are as follows:

Lube System Alarms - Additional turbine warning lights activated at values lower than the shutdown levels give a warning signal before the following malfunctions cause shutdowns:

Low Lube Oil Pressure
High Lube Oil Temperature
High Differential Pressure Across Lube Oil Filter
Low Lube Oil Level In Tank

Audible Alarm - An audible alarm activated by any warning or shutdown condition. An alarm silence button is included, mounted on the control console.

Temperature Monitoring System - Generator Windings. For added protection, this system provides warning and shutdown indications and a temperature meter to detect high temperature in the generator windings.

Electrical Metering Panel - Monitors the output of the generator set and provides manual control to synchronize the generator to the bus. The panel is normally mounted in the basic control console.

Individual Auto Synchronizer - Provides necessary logic to automatically synchronize to the bus through pushbutton control or remote signal. The auto synchronizer initiation pushbutton is located on the control cubicle.

KW Controller - Controls the real load (KW) on a unit paralleled to a large source. This load control is based on a preset dial location on the control cubicle.

KVAR/PF Controller - Maintains a constant reactive load (KVAR) output or constant PF, set by dial, on the generator set while the unit is paralleled to a large source.

Battery System - Nickel Cadmium, 24 VDC battery system, including batteries and charges are sized to supply the required control system power. The system is designed for indoor installation in a non-hazardous area.

Ancillary Equipment - Inlet System - The inlet to the Centaur gas turbine is protected by a self cleaning barrier air filter. This filter is recommended for locations where severe snow and ice conditions exist.

An inlet silencer is provided to attenuate the air compressor sound level.

Ancillary Equipment - Indoor steel enclosure installation where enclosure ventilation openings are to be ducted to the outside by customer. Standard features include.

Access doors
Ventilation fans
Three-coat polyamide/polyurethane paint system to Solar specification
Maintenance frame and trolley beam for engine removal
Removable panels

Preparation for Shipment - The unit will be prepared for short-term domestic shipment.

## Suspension Fired Combustion System

### Scope

The combustion system, as outlined below, will be supplied by EES and manufactured by Applied Combustion Technology, Incorporated of Orlando, Florida.

### Objectives

Utilization of refined biomass fuels in the production of electric power is contingent upon an efficient combustion system coupled with an appropriate turbine cycle to drive an electric generator. Solid fuels have a common characteristic which has traditionally interfered with the direct application of gas turbines to convert thermal energy into mechanical products of normal solid fuels destructively attack the highly stressed, rotating turbine components to the point of component failure. Consequently, the generation of electric power using a biomass fuel implies the integration of at least three fundamental subsystems:

1. An efficient combustion system capable of producing clean, high temperature combustion gases,
2. A practical heat exchanger, and
3. A gas turbine generator.

In order to overcome the problems associated with turbine life, a clean air cycle based upon the Brayton cycle is utilized. Air entering the compressor is pressurized from ambient conditions to typically 6 atmospheres and is passed through an air-gas heat exchanger where the compressor working fluid is heated to approximately 1450 degrees F. The primary working fluid is then expended to ambient pressure in the turbine producing work to drive the compressor, overcome system irreversibilities, and drive an electric generator. The heat exchanger utilized to heat the primary working fluid derives its energy from burner fueled with refined biomass product, and consequently, is an essential component in the electric generation system.

The suspension fired system is aimed specifically at meeting the combustion requirements of providing clean, high temperature gases to the heat exchanger section of a Brayton cycle gas turbine.

## Design Considerations

The conventional cyclone slagging furnace is essentially a horizontal cylinder of cylindrical construction with the interior walls lined with a plastic refractory. Refined biomass fuel in a pulverized form is fed from the pulverizer tangentially into the cyclone combustor. Primary air, equivalent to 15 to 20% of combustion requirements, is also added at the burner through a horizontal, tangential inlet at a velocity of 60 to 80 feet per second in the same rotational direction as the fuel. The air imparts a whirling action to the wood particles and discharges them into the larger cyclone cylinder where 600 degrees F. secondary air is introduced in the same tangential direction at the top of the cyclinder, imparting a further centrifugal action to the wood particles. Tertiary air (approximately 5% of the combustion air) is added at the inlet to cool the burner. Combustion is completed and the hot combustion gases exit through a reentrant throat at the outlet of the cyclone. The large particles adhere to the molten-slag-covered wall, where they are burned by the scrubbing action of the high-velocity (300 to 350 feet per second) secondary, air .

Although finer particles burn in suspension, most of the burning takes place near the wall of the cyclone. The heat release rate of 600,000 Btu per hour per square foot of interior surface results in temperatures in excess of 3,000 degrees F. at full load. The molten slag continuously flows through a taphole at the outlet end of the cyclone and eventually discharges into a water-filled slag tap where it is granulated.

To minimize unit downtime, two precipitation sections will be provided since the cleaning operation can be time consuming if not routinely done. The proposed unit is also equipped with a refractory lined test section in the hot gas exit side to permit gas sampling, cold tube impingement, and diagnostic testing of the exit gas stream. Continuous slag removal is provided by a bottomed tap and clinker transport auger.

The following diagnostic components are included as an integral part of the combustor:

1. Flow monitoring and control
2. Gas temperature probes
3. Wall temperature probes
4. Convective tube temperature probes (Precipitation Section)
5. Gas sampling probes and conditioning systems
6. Particulate sampling probes and conditioning systems
7. Windows for optical access, expecially to view ash deposition on tubes, and flame radiation. The main problem here is maintaining clean, unbroken windows.

The refined biomass slagging combustor system will be capable of fully automatic operation or manual override, as indicated below. The operator checks the entire unit and opens all necessary hand valves starts all necessary fans and pumps. At this time, the operator may initiate purge.

Logic checks:

1. Secondary Air
2. Secondary Air Flow - 25%
3. All Fuel Valves Closed
4. Pulverizer Off
5. Primary Air Off

A major factor affecting the operation of the cyclone burner is the temperature-viscosity characteristics of the ash slag. It has been established that a slag viscosity of up to 250 poises is sufficiently fluid for trouble-free tapping. Woods with ash viscosities greater than 250 poises at 2,600 degrees F. generally cannot be tapped from a conventional cyclone when containing more than 15% moisture and when using less than 600 degrees F. combustion air. It is well established that the flow characteristics of an ash in the liquid stage are largely dependent upon its chemical composition. The slag temperature needed to attain 250 poise viscosity measurements by determining the concentration of $SiO_2$, CaO, and MgO in the ash and then calculating the silica ratio. The use of the silica ratio has been found to give a reliable indication as to the relative ease of cyclone operations with various fuel types. Generally, fuels having an ash with a silica ratio less than 75 are not suitable for cyclone firing. This statement holds true for wood.

## Combustor Design

Based upon the cycle parameters of Eagle Energy Systems and presented in Figure 7, Applied Combustion Technology, Incorporated, is supplying a vertically firing (upward) slagging combustor for refined biomass fuels, as shown in Figures 2, 3 and 8.

The proposed design is based upon a rate controlled amount of refined biomass fuel being fed by an SCR auger into a 100 horsepower hammermill pulverizer. Pulverized refined biomass fuel is then conveyed by a 15 horsepower primary air fan where it is injected tangentially into the cyclone combustor (nominal rating of 60 million Btu per hour) below the mid point of the vertically firing (upward) unit. A turning section is provided at the exit and is equipped with a removable precipitation section which is designed to condense vapor phase ash materials. Our experience indicated this section should be water cooled to enhance vapor to solid deposition.

6. Furnace Pressure Not High
7. Turbine Exhaust Temperature Not High
8. Heat Exchanger Temperature Not High

Logic illuminates "purge ready" lamp.

At this time, operator may initiate purge by depressing purge start push-button. The logic locks into purge and starts 5 minute timer. Loss of any of the above purge permissions and logic will drop out of purge and reset timer to zero. When purge timer expires, it resets MFT and logic check.

1. Fuel Pressure Not High

2. Fuel Pressure Not Low
3. Fuel Temperature Correct (if required)
4. Items 1, 2, 6, 7 and 8 (Ref. pre-purge list)

Loss of any of the above will cause a trip. Logic illuminates "fuel ready" lamp. Operator may start auxiliary fuel at this time. Operator sets secondary air flow to light-off position and depresses burner start switch. Logic will automatically light pilot and main burner, then remove pilot. Operator warms chamber and brings auxiliary up to 40% firing rate with turbine on. At this time, operator may bring in biomass fuel. Operator raises bio fuel load slowly--this automatically reduces the auxiliary fuel to present unit in automatic operation and raises generation load to set point. Safety and trips, as required may be used, but as a minimum, we recommend the following main fuel trips:

1. High furnace pressure
2. High turbine exhaust temperature
3. High heat exchanger exhaust temperature
4. Low air flow
5. Loss secondary air fan
6. Lost flame detection
7. Loss all fuel
8. Turbine trip
9. Operator trip
10. Fuel out of operational parameters (i.e. high gas pressure)

Additional process controls, as required, can be slaved into the burner control and safety system during the design portion of the proposed project.

## Heat Exchanger

### Scope

The air heater heat exchanger shall be supplied by Coaltech-Farrier of York, Pennsylvania, or as determined at time of purchase and shall meet the following specifications:

#### Engine Air Side:

| | |
|---|---|
| Flow | 38.35 Lbs/Sec |
| Outlet Temperature | 1,450 degrees F. |
| Inlet Temperature | 597 degrees F. |
| Inlet Pressure | 134 PSIA |
| Pressure Loss | 5 PSI |

#### Hot Gas Side of Combustion Products:

| | |
|---|---|
| Flow | 41.80 Lbs/Sec |
| Gas Inlet Temperature | 1,625 degrees F. |
| Pressure Loss | 6" W.C. |

### Experience

The Coaltech-Farrier heat exchanger proposed for use with the Solar Centaur turbine engine is the standard "U" tube design. Coaltech-Farrier has been producing heat exchangers of this nature since the early 1950's under the name of Farrier. There is no problem with the 1,450 degree F. outlet temperature and 134 PSIA pressure requirements. Design of this unit is well within the state of the arts today.

Coaltech-Farrier has built over 60 units similar to the one being supplied in the EES system.

### Equipment Items

The following are included as part of the combustion system:

| Item | Description |
|---|---|
| 1. | Feeder - Auger, SCR, DC Motor, Reeves Drive |
| 2. | Hopper on Pulverizer |
| 3. | Pulverizer Schutte with Motor |
| 4. | P.A. Fan - Motor - Transition Piece |
| 5. | Burner 60MKB Slagging |
| | Body (include auxiliary fuel) |
| | Refractory |
| | Valve trains |
| 6. | Combustion Chamber |
| 7. | Turning Section, Inlet, Clean out, Damper |
| 8. | Test Section |
| 9. | Bypass Duct with Damper |
| 10. | Flange Duct to Heat Exchanger |
| 11. | Clinker Auger with Motor SCR |
| 12. | Gen II Modified |
| 13. | $O_2$ Trim |
| 14. | Air Transmitter |

### System Integration

Applied Combustion Technology and EES will provide technical expertise and engineering time to assure the successful integration of the ACT BioFlame Slagging Combustor into the total system.

## Size

The heat exchanger is 11' x 11' x 12' in size. The ducting from the turbine and combustor is included in the package.

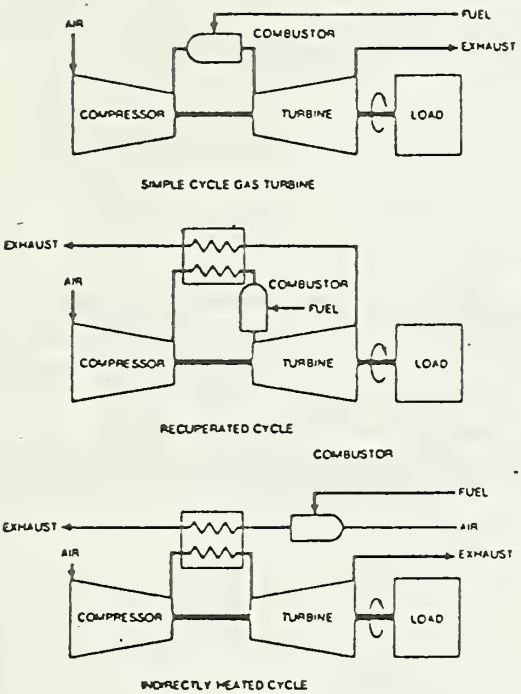
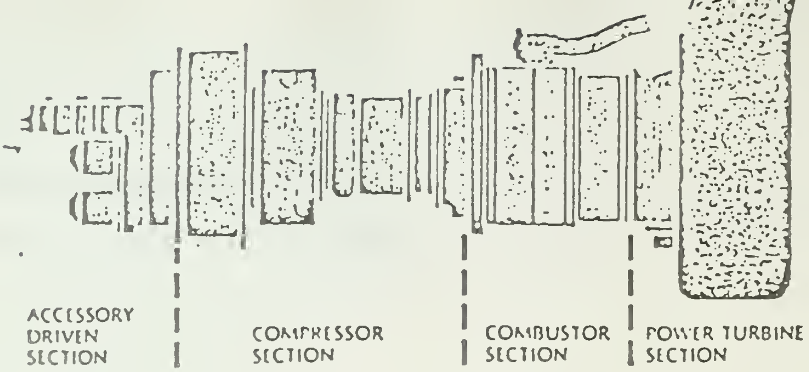
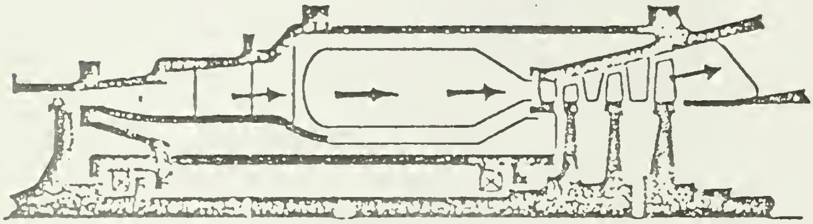


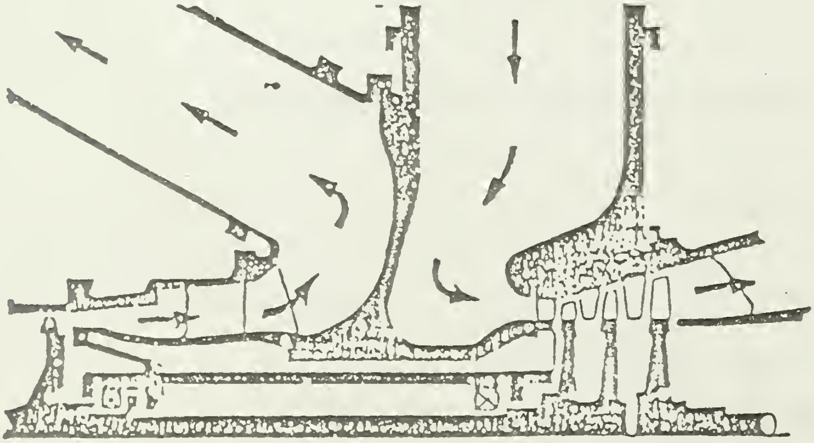
Figure 1. Alternative Gas Turbine Cycles



*Major engine sections of the simple-cycle Centaur engine.*



*Simple-cycle Centaur engine airflow.*



Indirect Heated *-cycle Centaur engine airflow.*

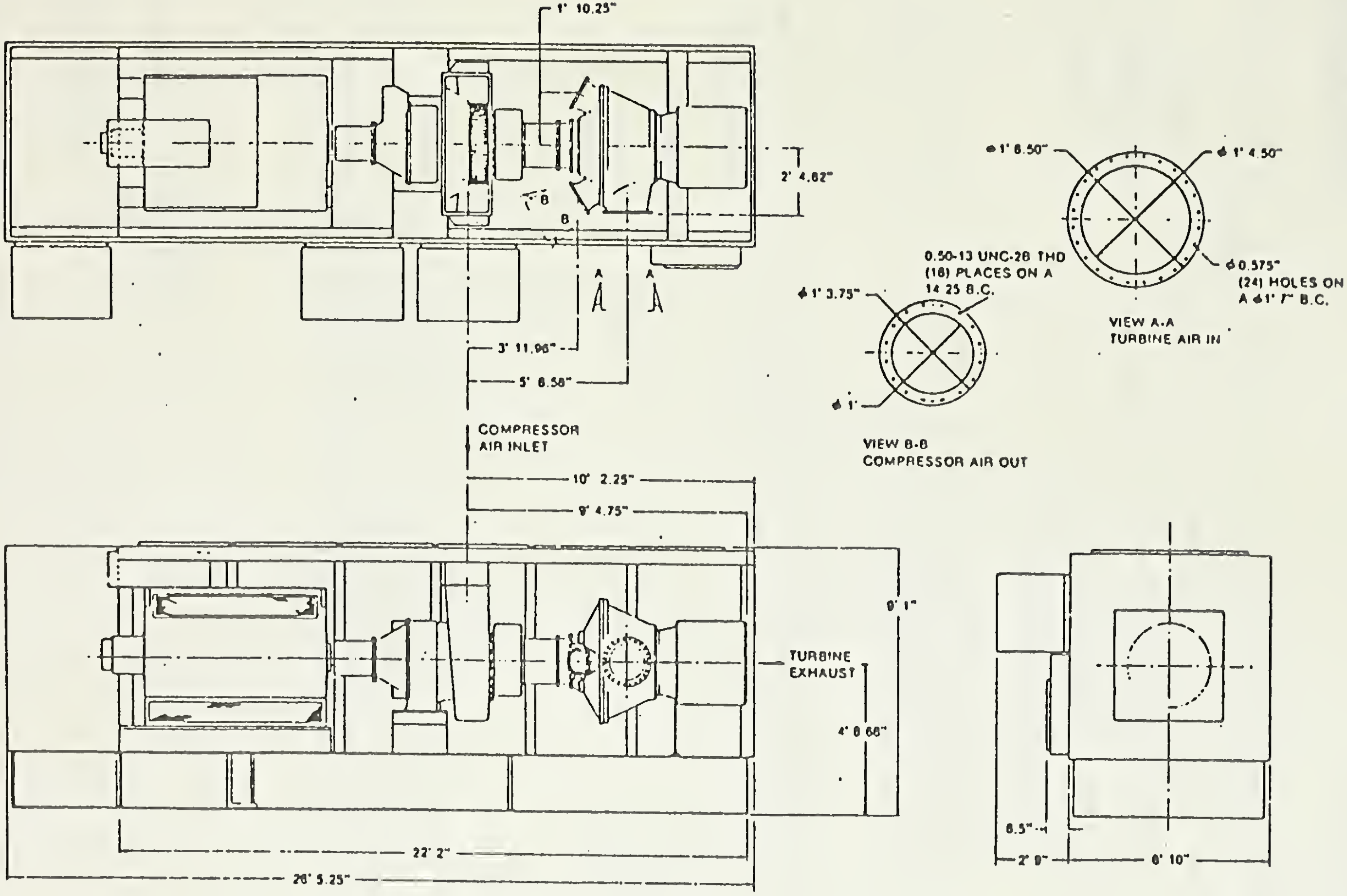


Figure 3. External Combustion Centaur Engine

## 6.4 JAYCOR LETTER

A nationally recognized engineering firm, JAYCOR has completed a study for Eagle Energy Systems, Inc., entitled "Steady-State Analysis of a Wood-Burning, Indirectly Heated Gas Turbine Generator System." The final report conclusively demonstrates the feasibility of the project. A correspondence summarizing the report follows.

JAYCOR

November 11, 1980

Mr. Mike Gleason
Eagle Energy Systems
P. O. Box 3452
Missoula, MT 59801

Dear Mike:

JAYCOR has reviewed the preliminary design of the proposed Eagle Energy Systems wood-burning, indirectly heated gas turbine electric generator system. The system includes a wood/biomass combustor supplied by Applied Combustion Technology, a gas-to-gas heat exchanger supplied by Coaltech Farrier, and a gas turbine supplied by SOLAR Turbines International.

Based upon component performance data supplied by these vendors, JAYCOR calculated the total system performance with an ambient pressure of 13.2 psia and temperatures of 59°F and 28°F. A summary of the system performance for each ambient condition is given below.

| Ambient Condition | 59°F | 28°F |
|---|---|---|
| Turbine Flow ~ lbs/sec | 38.35 | 39.9 |
| Net Electric ~ kW | 1731.2 | 2007.8 |
| Heat Exchanger Exhaust | | |
| Flow ~ lb/sec | 41.8 | 43.5 |
| Temperature ~ °F | 871.0 | 832.0 |

Calculations supporting these results are provided in the enclosed report. The report also contains the component data sheets that were used as a basis for performance calculations. Conversations with component vendors and reviews of the data indicate the components proposed are currently available. As a consequence of these facts, it is clear that the proposed system is feasible.

Yours truly,

James R Carlson

James R. Carlson, PE
Senior Engineer
Energy

Terry L. Greenlee

Terry L. Greenlee, Ph.D., PE
Manager, Systems Engineering
Energy Development Program

TLG/ts

Post Office Box 370 - 1401 Camino Del Mar • Del Mar, California 92014 • (714) 453-6580

# APPENDIX A

## SOLAR CENTAUR
## PERFORMANCE CURVES

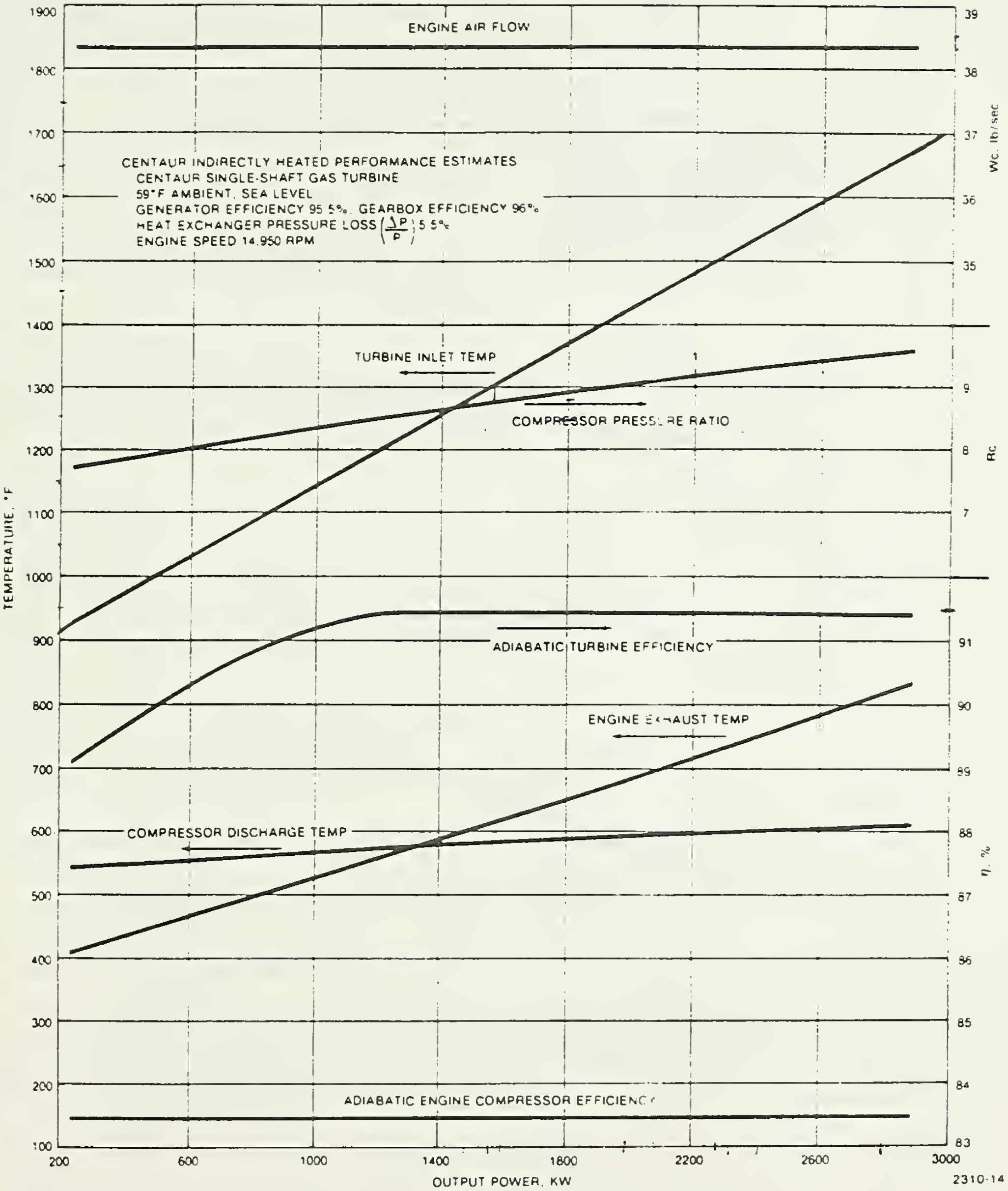


Figure 4. GS4000 Indirect Heated Output Power Estimates at 59°F

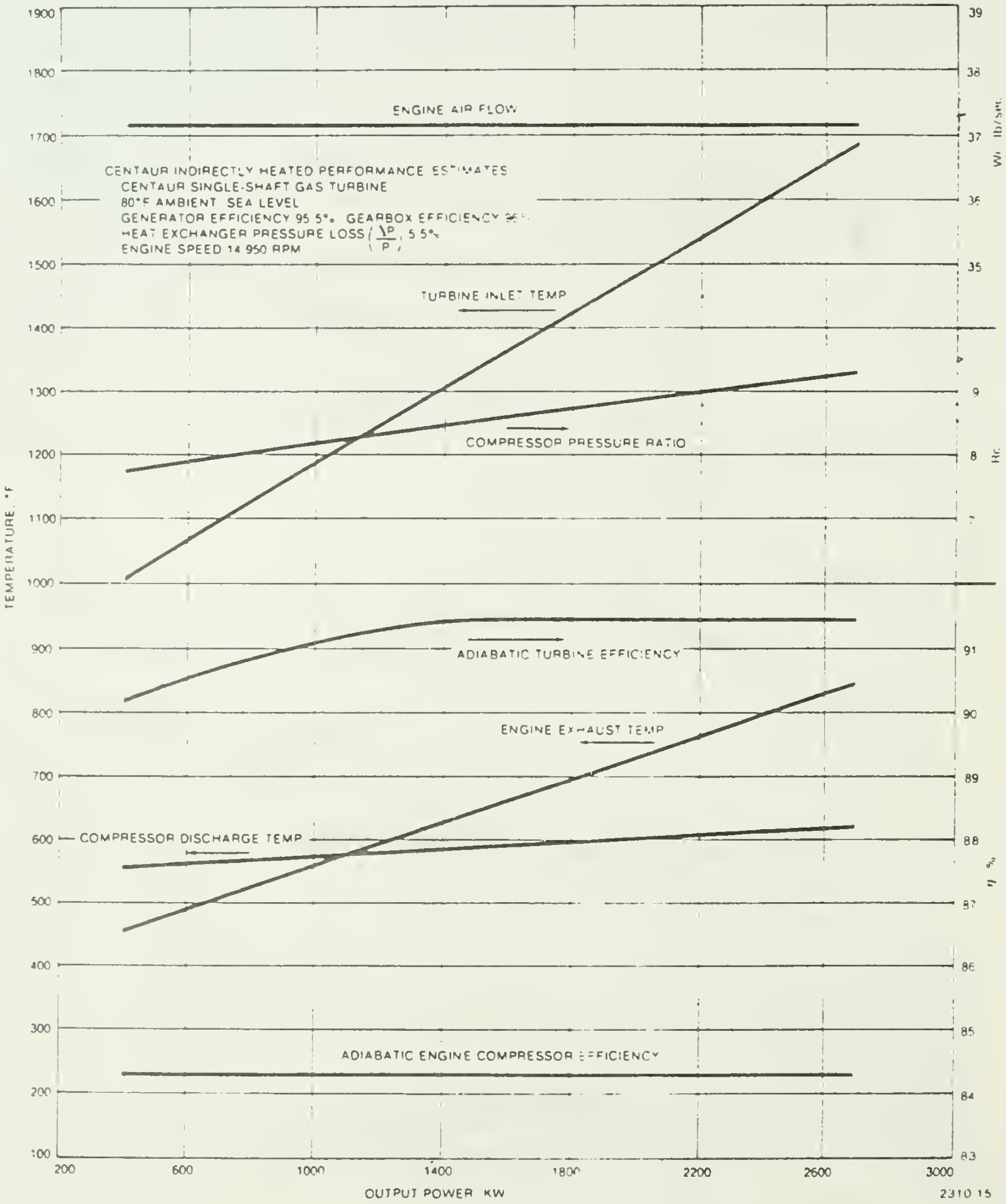


Figure 5. GS4000 Indirect Heated Output Power Estimates at 80°F

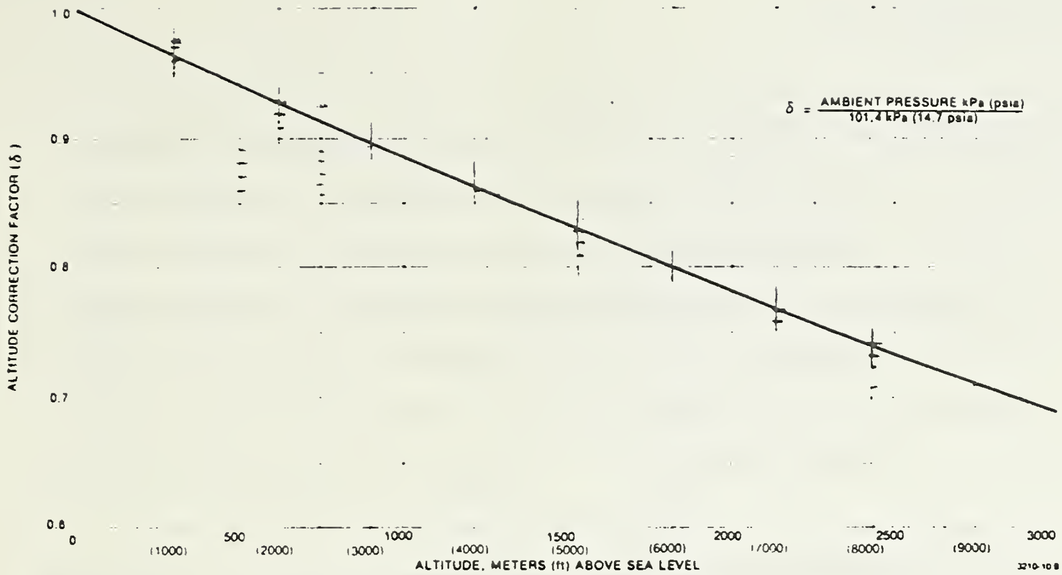


Figure 13-1. Performance Correction Factor for Altitude

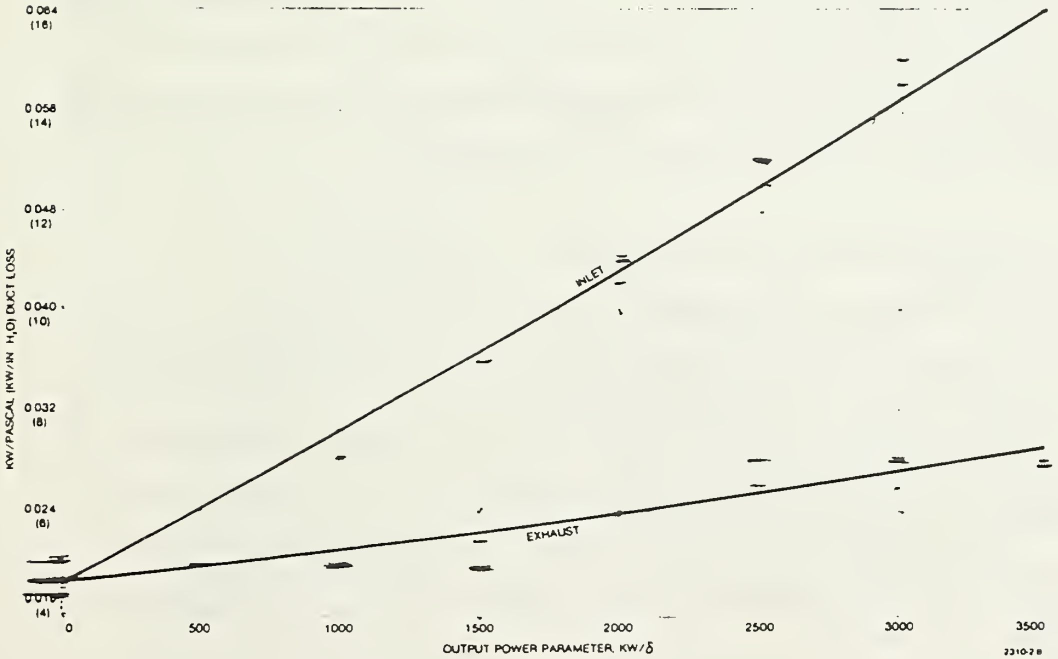


Figure 13-2. Inlet and Exhaust Power Loss

## 6.5 COMPUTER MODEL

The program was designed for the purpose of evaluating the performance (or output) of the Solar Centaur turbine engine/generator at various input conditions. Operating altitude, ambient temperature, and turbine inlet temperature can be varied in any desired combination. The program then calculates the output characteristics (temperature, mass flow, fuel rate, and net power output, to name a few). All of this can be easily accomplished in a matter of minutes.

It is to be noted that the program is not intended to aid in the selection of a suitable gas turbine engine, but rather pre-assumes the selection of the Solar Centaur GS 400 engine. In fact, the operating curves for this engine have been used as the basis for performance calculations in the program. One of the best uses of the program would be as an aid in optimizing flows after the facility has been built.

The accuracy of the model is verified by comparing the outputs for conditions (TAMB=60 F, EASL=3000 ft, TIT=1450 F), and (TAMB=30 F, EASL=3000 ft, TIT=1450 F) with the results of the Jaycor study. Although there are slight differences in assumptions in the two analyses, the resulting power outputs computed for the two ambient conditions agree to within 4% (for TAMB=30 F) and 2% (for TAMB=60 F). Thus the hand calculations shown in the Jaycor study support very well the output results of the computer model.

Also provided by the computer model are estimates of the overall cycle efficiency for each set of operating data, assuming 0%, 50%, and 100% utilization of heat exchanger "waste heat."

The combustion and turbine generator unit was modeled to predict the performance of the system at various operating conditions. Basically, the performance of the system, once designed and installed varies only with the operating set point of the turbine inlet temperature and the ambient conditions. Thus, the computer model was developed using only these as input data.

## Gas Turbine and Generator Package

The system modeled is a gas turbine fired indirectly through a heat exchanger. The Centaur engine GS 400, as manufactured by Solar Turbines, is the unit selected. The component arrangement of the system is as shown in Figure 1.

The following nomenclature is used throughout:

m = Mass flow rate (lbs/sec)
T = Temperature
S = Ideal temperature
P = Pressure
dP= Pressure drop
CR= Compression ratio
H = Enthalpy
MC= Moisture content
a = Ambient
C = Specific heat
k = Ideal gas constant
e = Efficiency
E = Effectiveness
q = Heat transfer rate
Q = Heat content of fuel at MC
FR= Fuel rate

The turbine is modeled using the thermodynamic equations for the Brayton Cycle and the performance characteristics of the referenced machine. The compression ratio is found to be a function of the turbine inlet temperature set (T3) point and the ambient temperature (T1). The equation for CR is simulated by using the known values in a polynomial regression of least squares. This method is used throughout when it is necessary to formulate a numerical expression using observed values (see Appendix B). with the CR known for the particular operating conditions, the Brayton Cycle equations are:

$$S2 = T1\ (CR)^{.276}$$

and:

$$T2 = (S2-T1)/e + T1$$

$$P2 = P1\ (CR)$$

The compressor efficiency is a function of the machine and the operating conditions. Again, a polynomial regression is used for a numerical expression to simulate it.

Knowing these values, and assuming a 5.5% pressure drop through the heat exchanger, the leaving conditions are calculated as follows:

$$S4 = T3/(P3/P4)^{.26}$$

$$T4 = T3-e\ (T3-S4)$$

Where e is the adiabatic turbine efficiency. The work of compression, turbine work and net work available are now calculated using the temperatures and mass flow rates. These values are at sea level and with no duct loss on the compressor inlet. These adjustments are made by calculating the power loss for the particular condition, again using a polynomial regression. The backpressure on the turbine from the combustion system is also accounted for.

Thus, the performance of the generator set can be predicted for any operating condition between 30F and 100F ambient and turbine inlet temperatures between 1300F and 1600F. See Appendix A for plots of the operating parameters.

### Combustor and Heat Exchanger

Once the operating conditions for the turbine are know, it is necessary to calculate the performance of the combustor and heat exchanger under these conditions.

A portion of the preheated air leaving the turbine is used as secondary air in the combustor and the rest is used as tertiary or diluent air. The combustor is operated so as to provide the necessary temperature and mass flow through the heat exchanger.

The mass balance yields the equation:

$$M5 = M4 = 2.2\ FR$$

where the term for the fuel rate includes the primary air mass flow rate.

The energy equations for the system are:

$$M4\ (H4-H2) + \dot{q}\ \text{loss} = \dot{m}5\ (H5=H6)$$

$$\dot{m}5\ (H5) = (FR)(Q) + 1.2\ H8\ (\text{air}) + \dot{m}4H7$$

The enthalpy for air and for the combustion gases are found by a numerical expression derived by a polynomial regression (see Appendix A). The equations are solved by assuming a mass flow rate through the combustor and using the method of successive substitution. Thus, all of the mass flow rates and energies are known for any operating condition of the turbine as set forth in the previous section.

## Results

The system was modeled using a TRS-80 computer with 64K memory and a Radio Shack VI line printer. A graph display pattern was formulated to print the results, along with the regular output. The program is presented in Appendix C, along with the output for various temperatures.

Figure 2 shows the results of the study for three turbine inlet temperatures between 30F and 100F. As these show, the net electrical energy increases as the ambient temperature decreases and the inlet temperature increases.

# APPENDIX B

# POLYNOMIAL REGRESSION WITH LEAST SQUARES FOR VARIOUS FUNCTIONS

```
[illegible]
NUMBER OF OBSERVATIONS IS  4

THE  0  ORDER OF X, THE COEFFICIENT IS  10.8212
THE  1  ORDER OF X, THE COEFFICIENT IS -5.06559E-03
THE  2  ORDER OF X, THE COEFFICIENT IS  2.50538E-06
```

80 F
Ambient

```
                        Y             Y                          PERCENT
      X               ACTUAL      CALCULATED       ERROR          ERROR
------------------------------------------------------------------------------

   1300.000           8.450         8.470          0.020          0.237
   1400.000           8.700         8.640         -0.060          0.690
   1500.000           8.800         8.860          0.060          0.681
   1600.000           9.150         9.130         -0.020          0.218
------------------------------------------------------------------------------


DARD DEVIATION=        0.0447
AGE PERCENT DEVIATION=        0.4567
MUM PERCENT DEVIATION=        0.6923


  PERCENT OF DATA IS WITHIN  5  PERCENT OF EQUATION.
  PERCENT OF DATA IS WITHIN  10  PERCENT OF EQUATION.
  PERCENT OF DATA IS WITHIN  15  PERCENT OF EQUATION.
  PERCENT OF DATA IS WITHIN  20  PERCENT OF EQUATION.
  PERCENT OF DATA IS WITHIN  25  PERCENT OF EQUATION.

A POINT        X              Y

  1           1300           8.2
  2           1400           8.45
  3           1500           8.65
  4           1600           8.85
```

100°F Ambient

```
C  OF SOLAR CENTAUR AS FUNCTION OF INLET TEMP(F)
THE NUMBER OF OBSERVATIONS IS  4

FOR THE  0  ORDER OF X, THE COEFFICIENT IS  5.41998
FOR THE  1  ORDER OF X, THE COEFFICIENT IS  2.15001E-03


                         Y               Y                                PERCENT
          X            ACTUAL        CALCULATED          ERROR             ERROR
-----------------------------------------------------------------------------------

      1300.000          8.200           8.215            0.015             0.183
      1400.000          8.450           8.430           -0.020             0.237
      1500.000          8.650           8.645           -0.005             0.058
      1600.000          8.850           8.860            0.010             0.113
-----------------------------------------------------------------------------------


STANDARD DEVIATION=       0.0137
AVERAGE PERCENT DEVIATION=       0.1476
MAXIMUM PERCENT DEVIATION=       0.2367

  00   PERCENT OF DATA IS WITHIN  5   PERCENT OF EQUATION.
 100   PERCENT OF DATA IS WITHIN  10   PERCENT OF EQUATION.
  00   PERCENT OF DATA IS WITHIN  15   PERCENT OF EQUATION.
  00   PERCENT OF DATA IS WITHIN  20   PERCENT OF EQUATION.
 100   PERCENT OF DATA IS WITHIN  25   PERCENT OF EQUATION.

DATA POINT       X              Y

      1         1300           8.2
      2         1400           8.45
      3         1500           8.65
      4         1600           8.85
```

# APPENDIX C

## COMPUTER PROGRAM
## AND OUTPUT

```
          C O M P U T E R   S I M U L A T I O N

          INDIRECTLY HEATED GAS FIRED TURBINE
          SOLAR CENTAUR GS400 GENERATOR PACKAGE


**************************************************************

INPUT DATA:

AMBIENT TEMPERATURE (F)                         =    30
ALTITUDE ABOVE SEA LEVEL (FT)                   =    3000
TURBINE INLET TEMPERATURE SETTING(F)            =    1550
PRESSERE LOSS ON ENGINE INLET(IN OF H2O)=    .5



OUTPUT DATA FOR GENERATER SYSTEM

COMPRESSOR RATIO                                =    9.95159
IDEAL TEMPERATURE AT COMP EXIT (F)              =    463.877
ACTUAL TEMPERATURE AT COMP. EXIT (F)            =    737.809
PRESSURE AT COMP. EXIT (psi)                    =    146.288
PRESSURE DROP THRU HEAT EXCHANGER (psi) =    8.04585
PRESSURE AT TURBINE INLET (psi)                 =    138.242
IDEAL TEMPERATURE AT TURBINE EXIT (F)           =    662.359
ACTUAL TEMPERATURE AT TURBINE EXIT (F)          =    737.809
ADIABATIC COMPRESSOR EFFICIENCY                 =    82.1857
ADIABATIC TURBINE EFFICIENCY                    =    91.5
MASS FLOW RATE THRU ENGINE (LB/SEC)             =    39.8105
WORK OF COMPRESSION (HORSEPOWER)                =    7420.56
TURBINE WORK (HORSEPOWER)                       =    11416.3
NET WORK AVAILABLE AT SHAFT (HORSEPOWER)=    3995.71

POWER GENERATED AFTER GENERATOR AND
GEAR LOSSES AT SEA LEVEL (KW)                   =    2730.27

POWER LOSS DUE TO ALTITUDE (KW)                 =    285.19
POWER LOSS DUE TO INLET PRES. LOSS(KW)          =    6.61298
POWER LOSS DUE TO BACKPRESSURE (KW)             =    65.0855

TOTAL POWER GENERATED (KW)                      =    2373.39


**************************************************************
```

```
************************************************************

OUTPUT DATA FOR COMBUSTER AND HEAT EXCHANGER

TEMPERATURE ENTERING HEAT EXCHANGER(F)              =  1775
TEMPERATURE LEAVING  HEAT EXCHANGER(F)              =  800.892
TEMPERATURE SEC. & TERTIARY AIR(F)                  =  722.809
ENTHALPY OF GAS ENTERING H.E. (BTU/LB)              =  580.052
ENTHALPY OF GAS LEAVING  H.E. (BTU/LB)              =  300.116
ENTHALPY OF AIR LEAVING COMPRESSOR(BTU/LB)          =  247.686
ENTHALPY OF AIR ENTERING TURBINE(BTU/LB)            =  522.946
HEAT TRANSFERED TO TURBINE AIR(BTU/HR)              =  4.38331E+07
ESTIMATED HEAT LOSS TO SURROUNDINGS(BTU/HR)         =  4.38331E+06
MASS FLOW THRU HEAT EXCHAMGER(LBS/SEC)              =  43.4952
PRIMARY AIR MASS FLOW RATE(LBS/SEC)                 =  2.00982
SECONDARY AIR MASS FLOW RATE(LBS/SEC)               =  11.389
TERTIARY AIR MASS FLOW RATE(LBS/SEC)                =  28.4216
FUEL RATE-WOOD @15% MOISTURE(TONS/HR)               =  3.34969
HEAT CONTENT OF LEAVING GAS STREAM(BTU/HR)          =  2.86829E+07
CYCLE EFFICIENCY USING 0% OF EXIT GAS ENERGY        =  15.114
CYCLE EFFICIENCY USING 50% OF EXIT GAS ENERGY       =  41.8729
CYCLE EFFICIENCY USING 100% OF EXIT GAS ENERGY      =  68.6318

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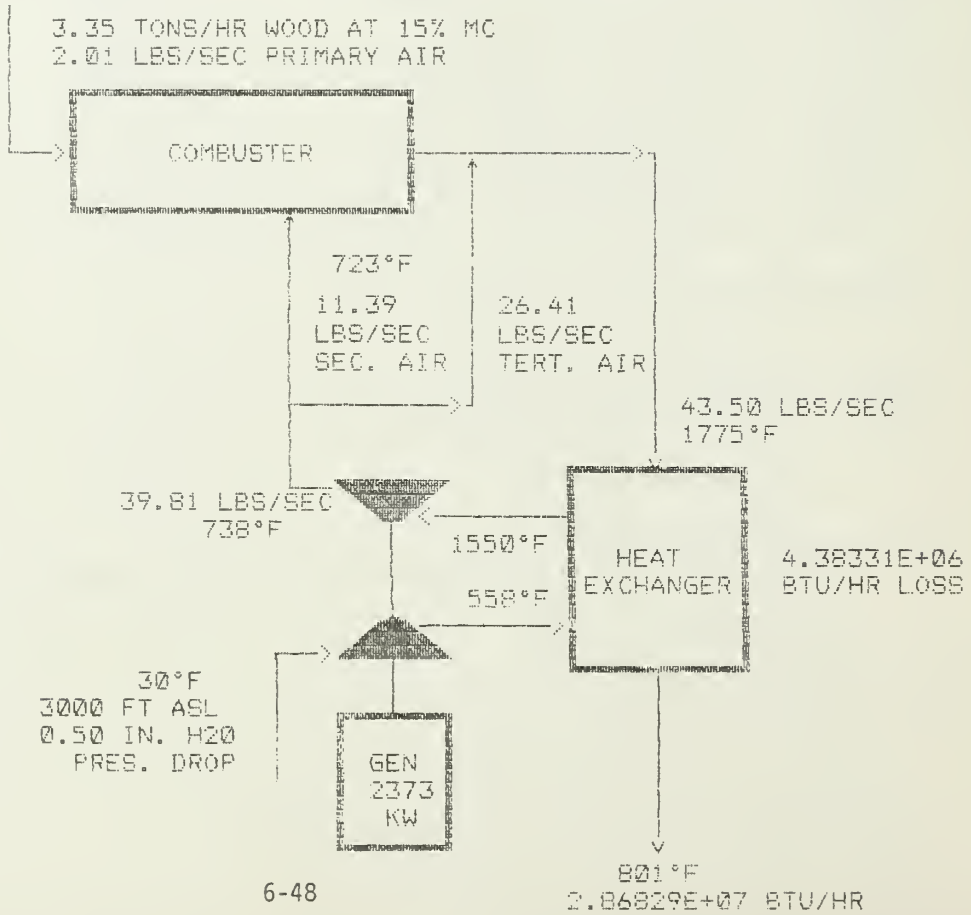

```
          COMPUTER  SIMULATION

          INDIRECTLY HEATED GAS FIRED TURBINE
          SOLAR CENTAUR GS400 GENERATOR PACKAGE



 ***********************************************************

 INPUT DATA:

 AMBIENT TEMPERATURE (F)                     =   100
 ALTITUDE ABOVE SEA LEVEL (FT)               =   3000
 TURBINE INLET TEMPERATURE SETTING(F)        =   1450
 PRESSERE LOSS ON ENGINE INLET(IN OF H2O)=   .5



 OUTPUT DATA FOR GENERATER SYSTEM

 COMPRESSOR RATIO                            =   8.53921
 IDEAL TEMPERATURE AT COMP EXIT (F)          =   552.184
 ACTUAL TEMPERATURE AT COMP. EXIT (F)        =   717.835
 PRESSURE AT COMP. EXIT (psi)                =   125.526
 PRESSURE DROP THRU HEAT EXCHANGER (psi) =   6.90395
 PRESSURE AT TURBINE INLET (psi)             =   118.622
 IDEAL TEMPERATURE AT TURBINE EXIT (F)       =   649.82
 ACTUAL TEMPERATURE AT TURBINE EXIT (F)      =   717.835
 ADIABATIC COMPRESSOR EFFICIENCY             =   84.8977
 ADIABATIC TURBINE EFFICIENCY                =   91.5
 MASS FLOW RATE THRU ENGINE (LB/SEC)         =   35.797
 WORK OF COMPRESSION (HORSEPOWER)            =   6731.83
 TURBINE WORK (HORSEPOWER)                   =   9253.86
 NET WORK AVAILABLE AT SHAFT (HORSEPOWER)=   2522.03

 POWER GENERATED AFTER GENERATOR AND
 GEAR LOSSES AT SEA LEVEL (KW)               =   1723.3

 POWER LOSS DUE TO ALTITUDE (KW)             =   180.007
 POWER LOSS DUE TO INLET PRES. LOSS(KW)      =   4.93284
 POWER LOSS DUE TO BACKPRESSURE (KW)         =   71.2194

 TOTAL POWER GENERATED (KW)                  =   1467.14


 ***********************************************************
```

```
**********************************************************

PUT DATA FOR COMBUSTER AND HEAT EXCHANGER

PERATURE ENTERING HEAT EXCHANGER(F)              =  1675
PERATURE LEAVING  HEAT EXCHANGER(F)              =  866.216
PERATURE SEC. & TERTIARY AIR(F)                  =  702.835
HALPY OF GAS ENTERING H.E. (BTU/LB)              =  550.2
HALPY OF GAS LEAVING  H.E. (BTU/LB)              =  318.389
HALPY OF AIR LEAVING COMPRESSOR(BTU/HR)          =  266.948
HALPY OF AIR ENTERING TURBINE(BTU/LB)            =  493.083
T TRANSFERED TO TURBINE AIR(BTU/HR)              =  3.23797E+07
IMATED HEAT LOSS TO SURROUNDINGS(BTU/HR)         =  3.23797E+06
S FLOW THRU HEAT EXCHAMGER(LBS/SEC)              =  38.8004
MARY AIR MASS FLOW RATE(LBS/SEC)                 =  1.63826
ONDARY AIR MASS FLOW RATE(LBS/SEC)               =  9.2835
TIARY AIR MASS FLOW RATE(LBS/SEC)                =  26.5135
L RATE-WOOD @15% MOISTURE(TONS/HR)               =  2.73044
T CONTENT OF LEAVING GAS STREAM(BTU/HR)          =  2.57865E+07
LE EFFICIENCY USING 0% OF EXIT GAS ENERGY        =  11.4619
LE EFFICIENCY USING 50% OF EXIT GAS ENERGY       =  40.9747
LE EFFICIENCY USING 100% OF EXIT GAS ENERGY      =  70.4874

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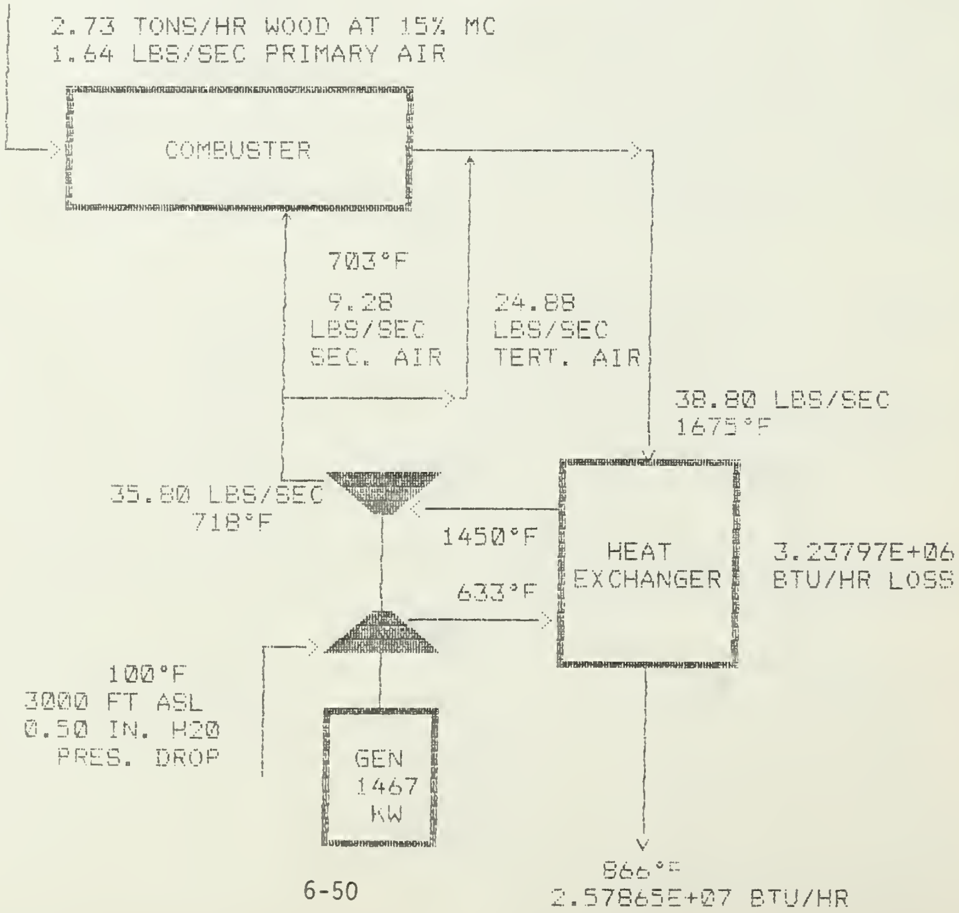


## 6.6 EQUIPMENT SPECIFICATIONS

| Equipment Number | Item |
|---|---|
| C-002 | Cogeneration Fuel Bin, prefab., 150 $ft^3$ capacity. |
| C-004 | Burner Fuel Cyclone, Champion, 29"Ø, with 1/4 HP, airlock. |
| C-006 | Fuel Hammermill, Champion Magnum, 11.5 x 32, 100 HP, 1800 RPM. |
| C-008 | Fuel Conveying Fan, (pulverised biomass to burner), Champion, 9.26, 15 HP. |
| C-010 | Cogeneration Burner, Applied Combustion Technology, vertical slagging type, 60 MMBTU rating. |
| C-012 | Heat Exchanger, Farrier, tube-in-shell type, designed for use with Solar Centaur (IHGT) 2 mw turbine. |
| C-014 | Gas Turbine/Generator set, Solar Turbines, 2.0 mw Centaur, recuperated, 480 volt generator. |
| D-002 | Dehydrator, Heil Co. Model 125-42, rated 21 tph @ 50% M.C., 14 tph @ 15% M.C. output, 45 HP drive and 3 HP inlet airlock. |
| D-004 | Dryer Cyclone, Heil Co., 53000 cfm. |
| D-006 | Secondary Dust Collector, Polutrol multi-cyclones. |
| D-008 | Dryer Fan, Heil Co., 53000 cfm, 12" $H_2O$, 200 HP. |
| D-010 | Screw Conveyor, Screw Conveyor Co., 12"Ø, 17'L, 1/2 HP. |
| E-002 | Switchgear, motor starters, etc., General Electric MCC (motor control center), main switch and distribution center capacitors, wiring and rigid conduit. |
| E-004 | Transformer Yard, Fenced in area approximately 20' x 20' with Westinghouse 2500 KVA 3 phase oil filled exterior trans. c/w foundation and wiring. |
| G-002 | Reel Scalper, prefab., 24 tph, 3/16" minus. |
| G-004 | Screw Conveyor, Screw Conveyor Co., 12"Ø, 18'L, 1/2 HP. |
| G-006 | Hammermill Metering Bin, prefab., 500 $ft^3$ capacity, live bottom. |

| | |
|---|---|
| G-008 | Hammermills, Champion Products, Magnum 20 x 44, 200 HP, 1800 RPM, w/magnetic humps and air bases. |
| G-010 | Metering Screws, Screw Conveyor Co., 12"Ø, 14'L, 1-1/2 HP, variable speed. |
| G-012 | Scalper Collector, Champion, 29"Ø, 2000 cfm, w/airlock. |
| G-014 | Hammermill Collectors, Champion, 52"Ø, 6000 cfm, w/airlock, 1/4 HP. |
| G-016 | Fuel Conveying Fan, Champion, Model 6.14, 10 HP, 1800 RPM. |
| G-018 | Metering Screw, Screw Conveyor Co., 8"Ø. 1/2 HP, variable speed. |
| G-020 | Hammermill Fans, Champion, 6000 cfm, Model 12.32, 20 HP, 1800 RPM. |
| G-022 | Process Material Metering Bin, prefab., 8000 $ft^3$ capacity, live bottom. |
| G-024 | Scalper Fan, Champion, Model 6.14, 2000 cfm, 10 HP, 1800 RPM. |
| G-026 | Metering Screws, Screw Conveyor Co., 12"Ø, 23'L, 2 HP, variable speed. |
| N-002 | Truck Dumper, Columbia Trailer Mfg., 16' x 45' steel deck, 50 ton capacity. |
| N-004 | Drag Chain, Link Belt, 20', variable speed drive, 10-24 tph. |
| N-006 | Covered Belt Conveyor, Thomas, 50' x 14" W, 24 tph, w/cover and IMI permanent magnet. |
| N-008 | Classifier, Dynamic Action, vibrating screen, 2'W x 26'L with 36" x 12' screen extension, 7-1/2 HP. |
| N-010 | Primary Hog, Lamb Gray Co., "Customizer", 300 HP, 1200 RPM, TEFC. |
| N-012 | Belt Conveyor, Thomas, 14'L, 24 tph rating. |
| N-014 | Infeed Surge Bin, prefab., 800 $ft^3$ capacity, live bottom. |
| N-016 | Metering Screw, Screw Conveyor Co., 18"Ø, variable speed, 20'L, 1-3/4 HP. |
| N-018 | Screw Feeder, Screw Conveyor Co., 24"Ø, 1 HP. |

| | |
|---|---|
| P-002 | Screw Conveyors, 12" dia., 20'L, 80 RPM, constant speed drive, 2 HP. |
| P-004 | Cooler Fan, Champion, Model 14.36, 11500 cfm, 45 HP. |
| P-006 | Cooler Cyclone, Champion, 74"Ø, 11500 cfm, w/airlock, 1.2 HP. |
| P-008 | Pellet Mills, California Pellet Mill Co., Series 8000, 500 HP drive, TEFC, with stainless steel mixer, dies, chrome plated rollers, die hoist, primary and secondary oil systems, and steam harness. |
| P-010 | Pellet Conveyor, Thomas Conveyor, 14"W, 24'L, 20 tph, 2 HP drive. |
| P-012 | Pellet Cooler, California Pellet Mill Co., Type 54 HRA 34, 11500 cfm, with vibration feeder. |
| P-014 | Vibrating Screen, Rotex, Model #21, 1-1/2 HP drive, 40" x 84", screen 1/4". |
| P-016 | Boiler Fuel Bin, 2000 $\text{ft}^3$ capacity. |
| P-018 | Boiler, 1500 lb/hr steam, 150 psi, 1.8 MMBTU, solid fuel burner, Wilburt Stoker. |
| S-002 | Vertical Bucket Elevator, Thomas Conveyor, BE 200, 2 HP drive, with consigner. |
| S-004 | Truck Loading Bin, SCAFCO, 2000 bushel capacity, with claim gates, 40 ton load. |
| S-006 | Vertical Bucket Elevator, Thomas Conveyor, 5000 cubic feet per hour, Model BE 800, 30'H, 5 HP drive. |
| S-008 | Belt Conveyor, Link Belt, 12"W, 50'L, with gate opening at 10" to fill truck loading bin, 3 HP drive. |
| S-010 | Screw Conveyor, 16" dia., 50 RPM, 30'L, 5 HP drive. |
| S-012 | Storage Bin, SCAFCO, 48' dia., 40' side wall, 67,215 bushel, 1300 ton storage on concrete pad. |
| S-014 | Truck Scales, Howe-Richardson, 80' steel platform with digital readout. |

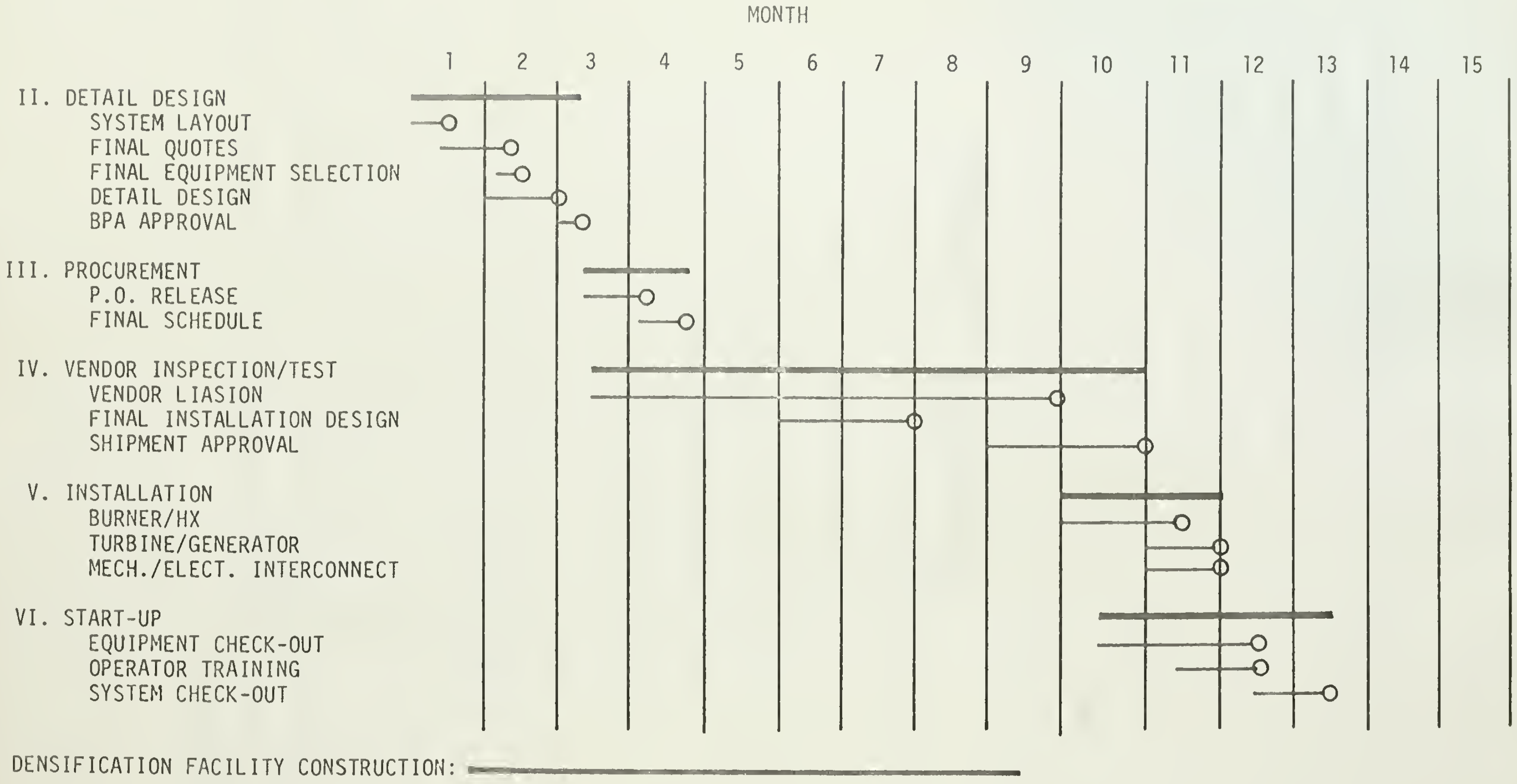
# PROJECT SCHEDULE

The total estimated time required to construct the proposed facility, including permits and preliminary engineering, detailed design and equipment purchase, construction installation, start-up and testing, is about 17 months. For the purposes of this report, the project schedule is assumed to begin with the detailed design / equipment purchase phase, since the permits and preliminary engineering work will have been done in the feasibility study portion of the project. The latter activities (constituting Phase I of the Project Schedule) would require approximately 4 of the 17 months. A description of Phase I follows:

I. Permits and Preliminary Design (4 to 6 months)
    a. Apply for environmental permits
    b. Turbine size trade-off study
    c. Conceptual system design
    d. Budgetary equipment quotes
    e. Concept approvals

Phases II through VII are detailed on the following graph, giving major elements of each phase and the time required to accomplish them. Note that if the proposed facility were subject to the PSD review process (described in Section 4 of this report) the time required for Phase I could involve up to a year for adequate modeling and establishing of the Baseline Concentrations in the vicinity of the proposed project. This could result in an overall time requirement of 24 months for completion of the project.

# PROJECT SCHEDULE



DATE: ____________ REVISION: ____________

# FINANCIAL

## 8.1 GENERAL

The accompanying financial analyses includes the following:

- Derivation of Operating Figures
- Break-even Analyses
- Return on Investment Over Economic Life
- Sensitivity Analyses

Derivation of Operating Figures:

Operating figures were derived, to the extent possible, from third party verification as follows:

| | |
|---|---|
| Bonneville Power Administration | Electrical Generation Income |
| Lincoln County Co-op | Equipment Costs and Operating Expenses |
| Eureka Sawmills | Raw Material Supply and Competitive Wage Base for Salaries |
| Insurance Brokers | Insurance Costs |
| Montana Tax Code | Property Tax Rates |
| Eagle Energy Staff | Performance Capacity; Parts, Repairs, and Maintenance Requirements |
| U.S. Forest Service | In-woods Raw Material Supplies and Availability |

The main problem in presenting realistic figures lies in the projected sales of wood fuel. As pointed out in Note 1 of the accompanying proforma, the operating figures are based on an ideal year of nearly 70% capacity. This translates to an output of 64,800 tons per year. Freight expense of delivering finished products has not been considered as it would be added to the base cost of fuel or paid by the end user of the product.

However, in order to be cost competitive with other forms of energy, principally natural gas, the delivered price cannot exceed approximately $80.00. This means the finished product must be marketed within 200-300 miles of the facility. While there may be a sufficient market within the mileage constraints, such market will not develop instantaneously and must be cultivated over time.

## Break-even Analysis:

A break-even analysis has been generated for both wood fuel production and cogeneration. The variable costs of generation are relatively low. This is the principal appeal of cogeneration. Fixed costs though are quite substantial due mainly to high debt service from expensive components. This results in the necessity of generating over 9 million killowatt-hours just to break even (generation capacity is just over 11 million kwh). Generating at the BPA's current rate of 37 mills/kwh simply is not profitable while being highly capital intensive.

Wood fuel fairs better from a break-even perspective. The facility has a capacity of 64,800 tons and must sell only 18,241 tons to break even (28% of capacity). However, there are two problems. First, a market must be developed and secondly, that market must be within the mileage constraints outlined above. It is projected that sales would not reach the break-even mark during the first three years of operation unless a major user (10 - 20,000 tons annually) was attracted.

## Return on Investment:

Return on investment is the most critical element of the financial structure. It fuses the elements of a profitable enterprise and the ability to attract equity investment to finance such enterprises. There are numerous ways to structure the enterprise to improve the return on investment. The most common form is leveraged investments with the majority of capital raised through debt financing, thereby limiting the need for substantial cash outlays from investors. This model has assumed a debt/equity ratio of 70/30. In the final analysis the structure evolves from a blend of the reliability of projections, the ability of an enterprise to support debt, and the degree of risk investors and financial institutions are willing to bear. All these elements have an effect on the rate of return an enterprise will generate.

## Sensitivity Analyses:

These analyses demonstrate that a manufacturing facility which relies heavily on inventories, and a facility that is capital intensive financed mainly with debt will be fairly sensitive to changes in raw material costs and interest rates. Fluctuations in other operating costs will have a much less noticeable impact on profits, as illustrated by a 67% increase in electrical rates resulting in only a 7% increase in the break-even point. Obviously, in attaining projected profit levels, steps should be taken to ensure that the most sensitive cost elements are kept within reasonable limits.

## Conclusion:

The first step in a project of this type begins with construction. In order to finance construction, equity investors must be attracted by suitable returns on their investments. While the concept of a wood fuel facility is extremely profitable when operating near capacity, the time and expense of penetrating and building a market for such a speculative fuel, although innovative and cost effective, would make attracting equity investment difficult.

## 8.2 PROFORMA

### EAGLE ENERGY SYSTEMS, INC.
### PRO FORMA STATEMENT (CASH FLOW BASIS)
### WOOD REFINING AND CO-GENERATION FACILITY

| | | |
|---|---|---|
| SALES | | |
| 1) Wood Fuel | $3,888,000 | |
| 2) Electrical Generation | 410,700 | |
| TOTAL REVENUE | | $4,298,700 |
| ANNUAL FIXED EXPENSE | | |
| 3) Debt Service | $ 705,024 | |
| 4) Insurance and Taxes | 68,186 | |
| 5) Office and Miscellaneous | 12,000 | |
| 6) Administrative Salaries | 56,250 | |
| | 841,460 | |
| ANNUAL VARIABLE EXPENSE | | |
| 7) Raw Material | 1,050,000 | |
| 8) Electrical | 219,582 | |
| 9) Direct Labor | 333,125 | |
| 10) Yard Expense | 74,520 | |
| 11) Repairs and Maintenance | 214,440 | |
| 12) Expendable Parts | 335,664 | |
| | 2,227,331 | |
| TOTAL EXPENSES | | $3,068,791 |
| NET CASH PROFIT | | $1,229,909 |

# EAGLE ENERGY SYSTEMS, INC.
## NOTES TO PRO FORMA
## WOOD REFINING AND COGENERATION FACILITY

### NOTE 1, WOOD FUEL:

The facility has the capacity to produce 13.9 tons per hour of refined wood fuel. 3.1 tons per hour of the output is consumed internally as fuel to produce hot gas for the dehydrator and the cogeneration system. The balance of 10.8 tons is available for sale. A capacity factor of 68.5% is assumed to allow for downtime for maintenance and any malfunctions in the system, which results in 6,000 hours of production annually. In order to be competitive with other fuel sources in the facility area, a per ton price of $60 f.o.b. plant site was derived. Freight costs are not considered as they would be an add-on to the per ton price. These financial statements are designed to present the ideal situation of the plant capacity being fully utilized. For a further discussion concerning competitive pricing and potential market, refer to the accompanying section on marketing of plant output.

10.8 TPH x 6,000 HRS x $60/T = $3,888,000

### NOTE 2, ELECTRICAL GENERATION:

The cogeneration system will produce an average output of 1850 KW. The system is designed to operate only when the wood refining process is operating, which is 6,000 hours per year as explained in Note 1. The B.P.A. is currently purchasing power from co-generators for $.037 per kilowatt-hour.

1850 KW x 6000 HRS x $.037/KWH = $410,700

### NOTE 3, DEBT SERVICE:

The total capital cost of the facility will be $4,624,568 (see attached equipment lists). It is anticipated the project will be funded 70% by debt and 30% by investor equity participation.

| | | |
|---|---|---|
| Capital Costs | $4,624,568 | |
| | x.70 | Debt Factor |
| | 3,237,198 | |
| Construction Period Interest | 231,010 | |
| Loan Origination Fee (5%) | 174,310 | |
| TOTAL DEBT | $3,641,618 | |

Annual Payment (15% Interest; 10 Year Amortization) - $58,752

EAGLE ENERGY SYSTEMS, INC.
NOTES TO PRO FORMA
WOOD REFINING AND COGENERATION FACILITY

## NOTE 4, INSURANCE & TAXES:

Insurance is based on quotes received from several agencies specializing in this type of coverage.

Property taxes are based on the state assessment rates for new industrial property. A mill levy rate of 300 mills is assumed.

| | |
|---|---|
| Insurance | $47,375 |
| Taxes | 20,811 |
| | $68,186 |

## NOTE 5, OFFICE & MISCELLANEOUS:

This expense covers the general overhead costs for telephones, office supplies, etc.

## NOTE 6, ADMINISTRATIVE SALARIES:

| | |
|---|---|
| Manager | $35,000 |
| Secretary/Bookkeeper | 10,000 |
| | $45,000 |
| Employee Benefits (Insurance, Employer's Share of Payroll Taxes, etc.) | 11,250 |
| | $56,250 |

## NOTE 7, RAW MATERIAL:

Raw material will be contracted from several sources. For a detailed discussion, refer to the appropriate section in this report. Based on quantities available from the various sources and cost differentials among the sources, a weighted average cost of $12.50 per bone-dry ton delivered to the facility was derived. The facility requires an input of 14 tons per hour of which part is used internally for fuel as explained in Note 1 above.

14 TPH x 6,000 HRS x $12.50/TON = $1,050,000

## NOTE 8, ELECTRICAL:

The entire system requires a maximum of 1592.9 KW of electrical power. A commercial rate of $.03/KWH is assumed. Average system usage will be approximately 1219.9 KW.

1219.9 KW x $.03/KWH x 6,000 HRS = $219,582

## EAGLE ENERGY SYSTEMS, INC.
## NOTES TO PRO FORMA
## WOOD REFINING AND COGENERATION FACILITY

### NOTE 9, DIRECT LABOR:

The facility will operate 3 shifts daily and each shift will require 4 employees.

Pellet Mill Operator (Mill Wright) - Operates pellet mills and responsible for overall operation of facility including cogeneration - $11/Hr.

Yard Man - Responsible for raw material infeed system and physical maintenance of raw material inventory - $9.50/Hr.

Dryer Operator - Operates dryer and infeed systems - $11.00/Hr.

Maintenance Man - Daily routine maintenance and repairs - $9.50/Hr.

| | |
|---|---|
| 2 men @ $11.00/Hr. x 6,500 hrs. = | $143,000 |
| 2 men @ $9.50/Hr. x 6,500 hrs. = | 123,500 |
| | 266,500 |
| Employee Benefits | 66,625 |
| | $333,125 |

### NOTE 10, YARD EXPENSE:

Expense of operating and maintaining a front-end loader used for raw material infeed and inventory management.

$1.15/Ton x 64,800 Tons = $74,250

### NOTE 11, REPAIRS & MAINTENANCE:

Includes both ordinary and extraordinary repairs requiring out-of-house craftsmen.

| | | |
|---|---|---|
| $2.80/Ton x 64,800 Tons = | $181,440 | Wood Refining |
| | 33,000 | Co-Generation |
| | $214,440 | |

### NOTE 12, EXPENDABLE PARTS:

Includes frequently needed consumables (grease, dies, rollers, etc.) and major consumables (engine overhauls, replacing worn out equipment, etc.).

$5.18/Ton x 64,800 Tons = $335,664

EAGLE ENERGY SYSTEMS, INC.
NOTES TO PRO FORMA
WOOD REFINING AND COGENERATION FACILITY

* * * * * * * * * *

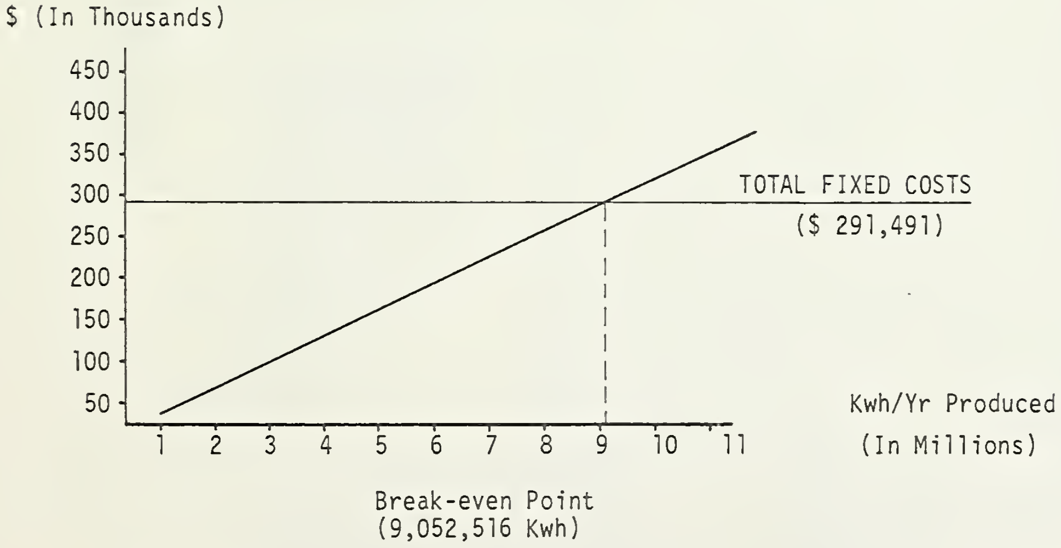
Eagle Energy Systems, Inc. currently has two experts in wood refining operations on staff. Each has been responsible for operating a wood pellet facility. Many of the foregoing operating expenses are based on their experience in the field and adjusted for any variables that could be quantified.

## 8.3 COST ANALYSES - COGENERATED ELECTRICITY AND WOOD FUEL PRODUCED

### EAGLE ENERGY SYSTEMS, INC.
### COST ANALYSES
### WOOD REFINING AND COGENERATION FACILITY

Cogeneration

| | |
|---|---|
| Variable Cost/Kwh: | |
| Electrical | $ .0018 |
| Repairs & Maintenance | .0030 |
| Total Variable Cost/Kwh | $ .0048 |
| Fixed Costs: | |
| Debt Service | $243,045 |
| Insurance & Taxes | 46,446 |
| Office & Misc | 2,000 |
| Total Fixed Costs | $291,491 |



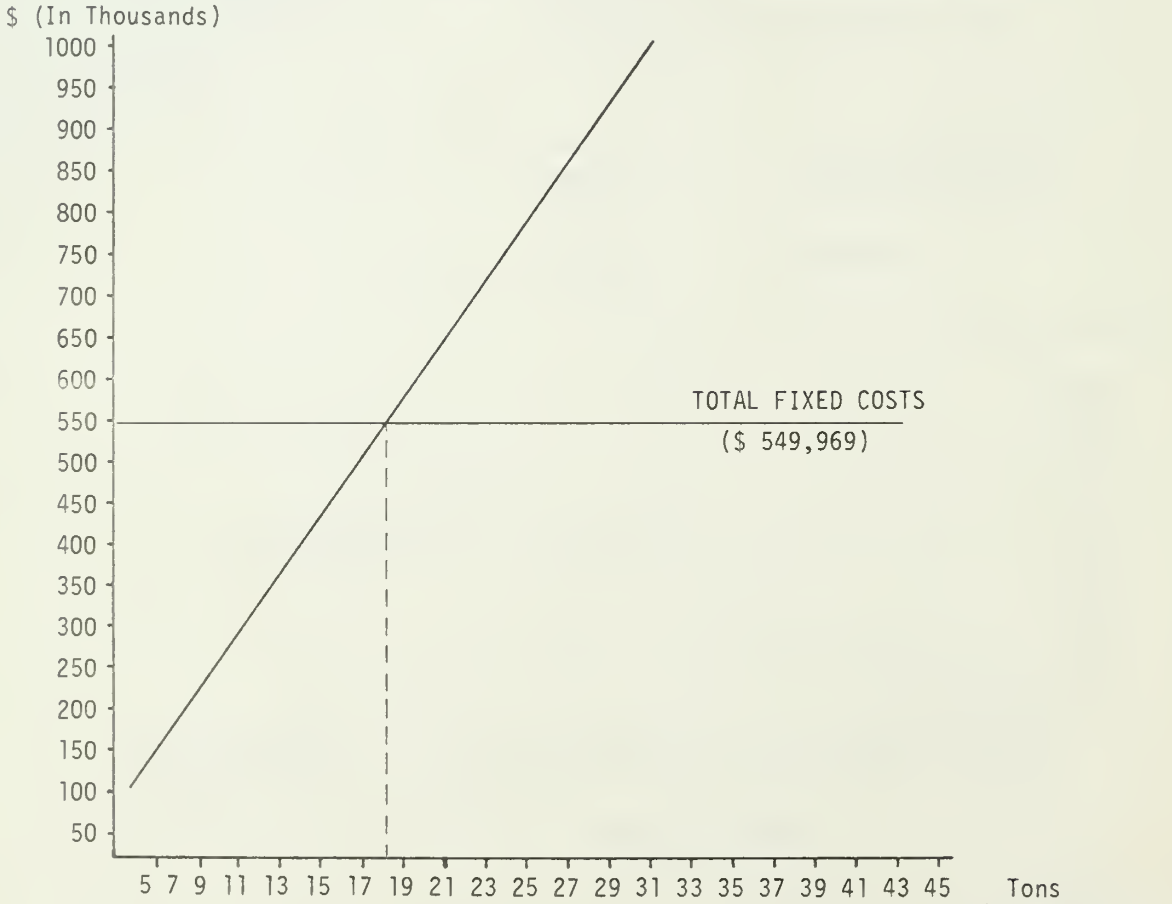
| | |
|---|---|
| Sale Price/Kwh | $ .0370 |
| Variable Cost/Kwh | .0048 |
| Contribution Margin | $ .0322 |

## EAGLE ENERGY SYSTEMS, INC.
## COST ANALYSES
## WOOD REFINING AND COGENERATION FACILITY

### Wood Fuel

| Variable Cost/Ton: | |
|---|---|
| Raw Material | $12.50 |
| Electrical | 3.08 |
| Direct Labor | 5.14 |
| Yard Expense | 1.15 |
| Repairs & Maint. | 2.80 |
| Expendable Parts | 5.18 |
| Total Variable Cost | $29.85/Ton |

| Fixed Costs: | |
|---|---|
| Debt Service | $461,979 |
| Insurance & Taxes | 21,740 |
| Office & Misc | 10,000 |
| Admin. Salaries | 56,250 |
| Total Fixed Cost | $549,969 |



Break-even Point
(18,241 Tons)

| | | |
|---|---|---|
| Sale Price/Ton of pellets = | $60.00 | |
| Variable Cost/Ton | 29.85 | |
| Contribution Margin | $30.15 | Amount per ton available to cover fixed costs. |

## 8.4 PAYBACK ANALYSES

EAGLE ENERGY SYSTEMS, INC.
ECONOMIC ANALYSIS (TEN YEAR)
WOOD REFINING AND COGENERATION FACILITY

| | | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 | YEAR 6 | YEAR 7 | YEAR 8 | YEAR 9 | YEAR 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) | Total Sales | $4,298,700 | $4,642,596 | $5,014,004 | $5,415,123 | $5,848,334 | $6,315,201 | $6,821,497 | $7,367,312 | $7,956,594 | $8,593,121 |
| 3) | Total Expense | 3,068,791 | 3,365,850 | 3,691,664 | 4,049,017 | 4,440,962 | 4,873,847 | 5,342,345 | 5,859,484 | 6,426,683 | 7,048,785 |
| | NET CASH PROFIT | $1,229,909 | $1,276,746 | $1,322,340 | $1,366,106 | $1,407,372 | $1,441,354 | $1,479,152 | $1,507,732 | $1,529,911 | $1,544,336 |

Simple Payback - 1.1 Years (Based on Invested Equity of $1,387,370)

Internal Rate of Return = 91% on Equity - This rate of return does not account for effect of taxes, both benefits (tax credits, accelerated depreciation, etc.) and costs (tax liability, depreciation, recapture, etc.) The tax effects depend on several factors beyond the scope of this overview including: What year the project begins (each year may be covered by a different tax law), what types of entity are the investors (corporation, partnership, etc.).

NOTE 1, TOTAL SALES:

Ten years is considered to be the economic life of the facility. Year 1 figures are from the accompanying pro forma statement. Sales are escalated at an annual rate of 8% in years 2 through 10.

NOTE 2, TOTAL EXPENSE:

Year 1 total expense is from the accompanying pro forma statement. For inflation adjustment factor see below.

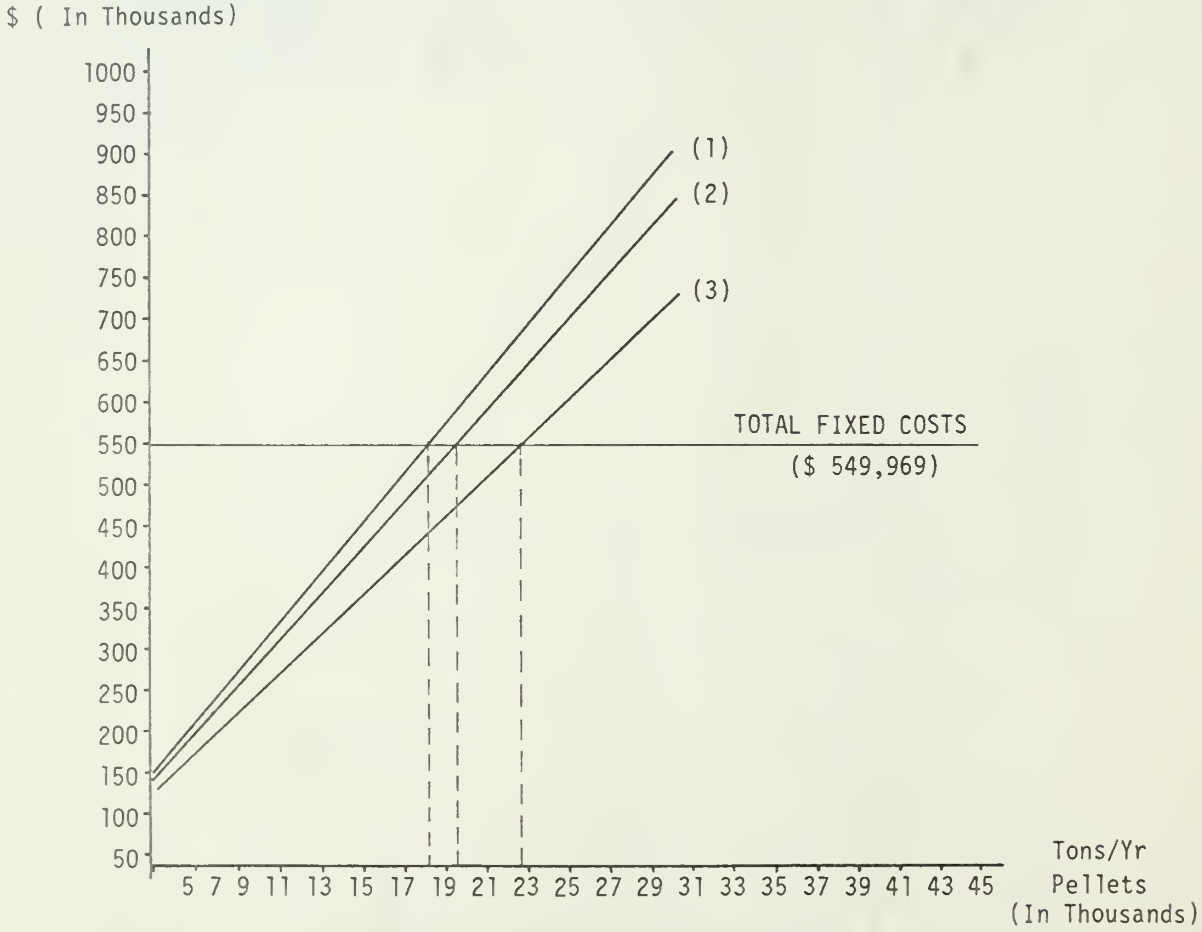
| | Escalator |
|---|---|
| Debt Service | 0% |
| Insurance & Taxes | 12% |
| Office & Miscellaneous | 10% |
| Administrative Salaries | 10% |
| Raw Material | 15% |
| Electrical | 15% |
| Labor | 9% |
| Yard Expense | 9% |
| Repairs & Maintenance | 10% |
| Expendable Parts | 10% |

## 8.5 SENSITIVITY ANALYSES

### EAGLE ENERGY SYSTEMS, INC.
### COST ANALYSES
### WOOD REFINING AND COGENERATION FACILITY

Sensitivity Analysis

Raw Material Costs



Break-even Point When Raw Material Cost is:

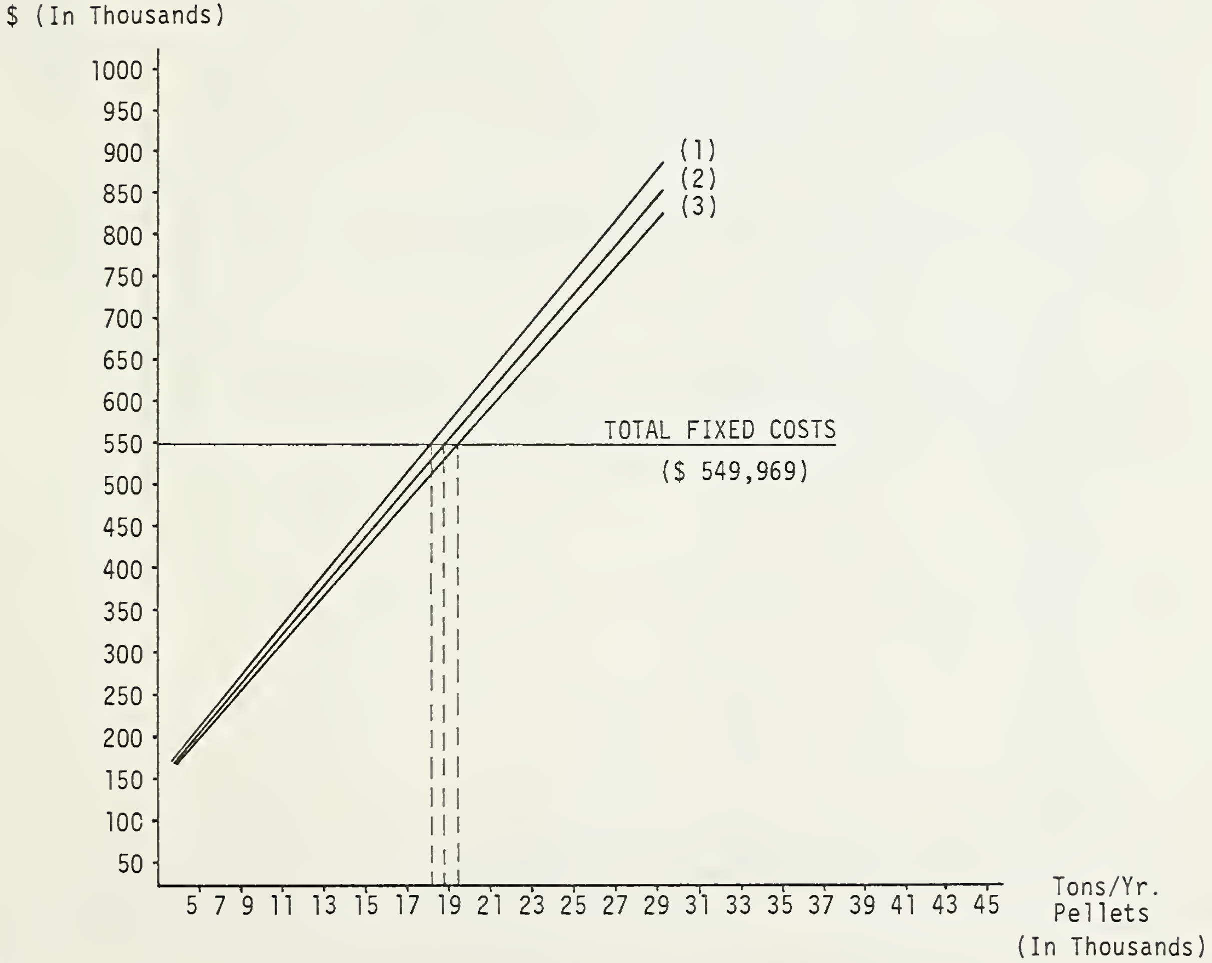
(1) $12.50 - 18,421 Tons

(2) $14.50 - 19,537 Tons

(3) $18.50 - 22,773 Tons

## Sensitivity Analysis

### Electricity Costs



Break-even Point When Electrical Rate is:

(1) $.03/KWH - 18,241 Tons

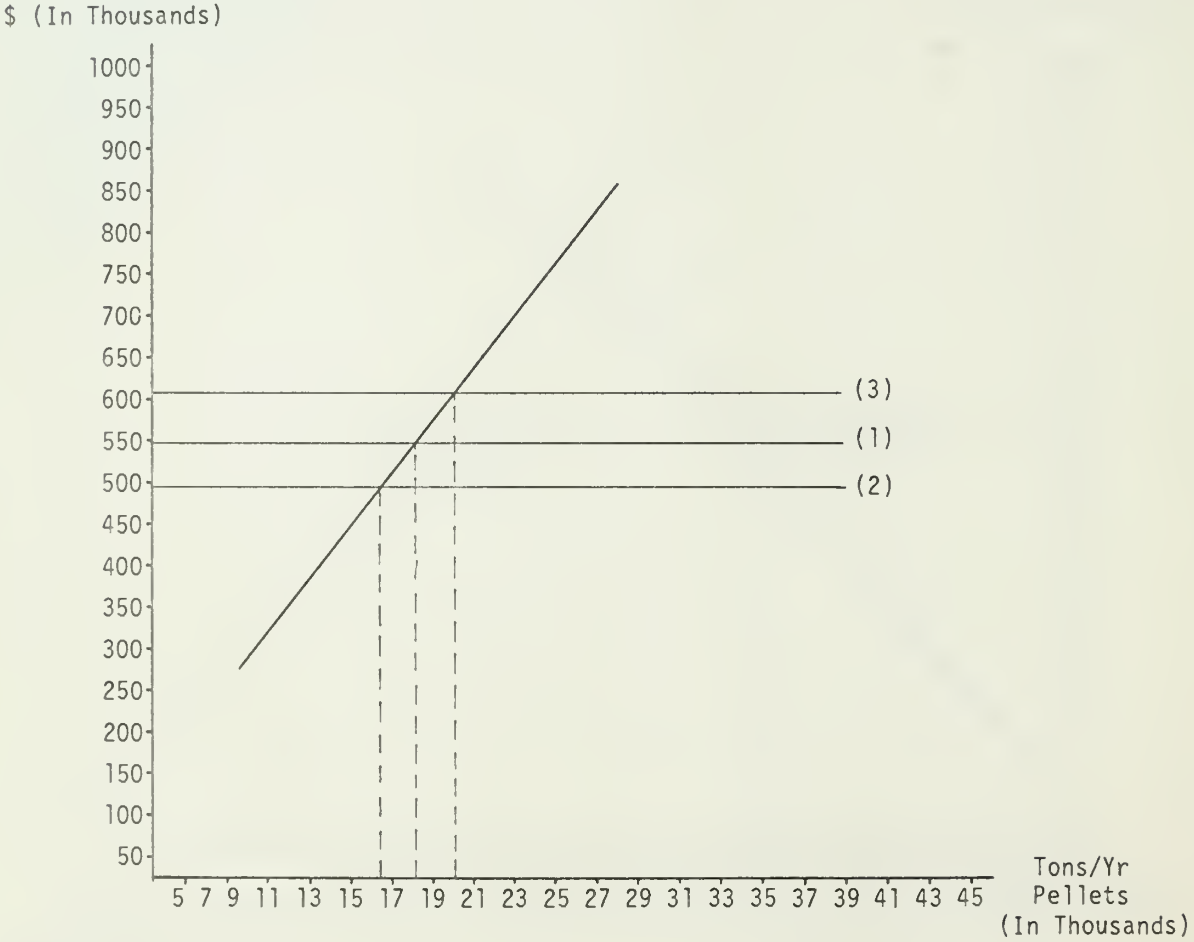
(2) $.04/KWH - 18,879 Tons

(3) $.05/KWH - 19,572 Tons

EAGLE ENERGY SYSTEMS, INC.
COST ANALYSES
WOOD REFINING AND COGENERATION FACILITY

## Sensitivity Analysis

### Interest Rates



Break-even Point When Interest Rate is:

(1) 15% - 18,241 Tons

(2) 12% - 16,544 Tons

(3) 18% - 20,031 Tons

# Estimate Worksheet

PROJECT DNRC GRANT # 467-811

EAGLE
ENERGY
SYSTEMS
North 1322 Post Street
Spokane, Washington 99201

| DESCRIPTION | | QUANTITY | COST | | LABOR-MATERIAL | TOTAL COST IN PLACE | REMARKS |
|---|---|---|---|---|---|---|---|
| | | | UNIT PRICE | AMOUNT | | | |
| G-020 | Hammermill Fans | 2 | 2,500 | 5,000 | 3,000/1,500 | 9,500 | |
| G-024 | Scalper Fan | 1 | 900 | 900 | 400/150 | 1,450 | |
| P-004 | Cooler Fan | 1 | 4,013 | 4,013 | 975/500 | 5,488 | |
| G-026 | Metering Screws | 2 | 5,500 | 11,000 | 450/100 | 11,550 | |
| P-002 | Screw Conveyors | 2 | 5,200 | 10,400 | 1,600/500 | 12,500 | |
| P-008 | Pellet Mills | 2 | 150,000 | 300,000 | 20,000/10,000 | 330,000 | |
| P-010 | Pellet Conveyor | 1 | 4,500 | 4,500 | 1,440/300 | 6,240 | |
| P-012 | Pellet Cooler | 1 | 27,500 | 27,500 | 1,200/250 | 28,950 | |
| P-014 | Vibrating Screen | 1 | 9,286 | 9,286 | 1,600/1,000 | 11,886 | |
| S-002 | Vertical Bucket Elevator | 1 | 18,000 | 18,000 | 3,200/450 | 21,650 | |
| S-004 | Truck Loading Bin | 1 | 35,000 | 35,000 | 5,000/1,500 | 41,500 | |
| S-008 | Belt Conveyor | 1 | 20,000 | 20,000 | 4,000/2,500 | 26,500 | |
| S-006 | Vertical Bucket Elevator | 1 | 9,000 | 9,000 | 3,800/800 | 13,600 | |
| S-010 | Screw Conveyor | 1 | 5,000 | 5,000 | 2,700/450 | 8,150 | |
| S-012 | Storage Bin | 1 | 50,000 | 50,000 | 5,000/2,500 | 57,500 | |
| P-016 | Boiler Fuel Bin | 1 | 11,800 | 11,800 | 4,800/500 | 17,100 | |
| P-018 | Boiler | 1 | 40,000 | 40,000 | 10,000/5,000 | 55,000 | |
| C-002 | Cogen. Fuel Bin | 1 | 4,500 | 4,500 | 1,500/500 | 6,500 | |
| C-004 | Burner Fuel Cyclone | 1 | 2,250 | 2,250 | 1,800/400 | 4,450 | |
| C-006 | Fuel Hammermill | 1 | 18,000 | 18,000 | 2,700/500 | 21,200 | |
| C-008 | Fuel Conveying Fan | 1 | 2,200 | 2,200 | 800/650 | 3,650 | |
| C-010 | Cogeneration Burner | 1 | 160,000 | 160,000 | 50,000/20,000 | 230,000 | |
| C-012 | Heat Exchanger | 1 | 240,000 | 240,000 | 40,000/10,000 | 290,000 | |
| C-014 | Turbine Generator | 1 | 1,000,000 | 1,000,000 | 50,000/10,000 | 1,060,000 | |

PROJECT DNRC GRANT # 467-811

EAGLE
ENERGY
SYSTEMS
North 1322 Post Street
Spokane, Washington 99201

|  | DESCRIPTION | QUANTITY | COST |  | LABOR-MATERIAL | TOTAL COST IN PLACE | REMARKS |
|---|---|---|---|---|---|---|---|
|  |  |  | UNIT PRICE | AMOUNT |  |  |  |
| N-004 | Drag Chain | 1 | 23,000 | 23,000 | 2,400/1,500 | 26,900 |  |
| N-006 | Covered Belt Conveyor | 1 | 45,000 | 45,000 | 6,500/3,500 | 55,000 |  |
| N-008 | Classifier | 1 | 30,000 | 30,000 | 2,000/1,500 | 33,500 |  |
| N-010 | Primary Hog | 1 | 125,380 | 125,380 | 2,400/2,000 | 129,780 |  |
| N-012 | Belt Conveyor | 1 | 4,000 | 4,000 | 1,000/500 | 41,500 |  |
| N-014 | Infeed Surge Bin | 1 | 10,400 | 10,400 | 2,800/1,200 | 14,400 |  |
| N-016 | Metering Screw | 1 | 6,000 | 6,000 | 1,280/350 | 7,630 |  |
| N-018 | Screw Feeder | 1 | 4,800 | 4,800 | 1,280/375 | 6,455 |  |
| D-002 | Dehydrator Drum | 1 | 337,237 | 337,237 | 75,000/25,000 | 437,237 |  |
| D-004 | Dryer Cyclone | 1 | 6,400 | 6,400 | 1,600/1,000 | 9,000 |  |
| D-006 | Secondary Dust Collector | 1 | 168,000 | 168,000 | 11,000/3,500 | 182,500 |  |
| D-008 | Dryer Fan | 1 | 45,000 | 45,000 | 3,000/1,000 | 49,000 |  |
| D-010 | Screw Conveyor | 1 | 5,850 | 5,850 | 640/200 | 6,690 |  |
| G-002 | Reel Scalper | 1 | 11,650 | 11,650 | 1,600/500 | 13,750 |  |
| G-004 | Screw Conveyor | 1 | 3,000 | 3,000 | 600/250 | 3,850 |  |
| G-006 | Hammermill Metering Bin | 1 | 10,400 | 10,400 | 1,500/500 | 12,400 |  |
| G-101 | Metering Screws | 2 | 6,000 | 12,000 | 2,400/800 | 15,200 |  |
| G-008 | Hammermills 200 HP | 2 | 18,000 | 36,000 | 5,400/1,000 | 42,000 |  |
| G-022 | Metering Bin | 1 | 5,000 | 5,000 | 1,500/600 | 7,100 |  |
| G-016 | Fuel Conveying Fan | 1 | 3,000 | 3,000 | 750/325 | 4,075 |  |
| G-018 | Metering Screw | 1 | 2,750 | 2,750 | 800/275 | 3,825 |  |
| G-012 | Scalper Collector | 1 | 4,500 | 4,500 | 750/400 | 5,650 |  |
| G-014 | Hammermill Collectors | 2 | 5,500 | 11,000 | 4,000/2,500 | 17,500 |  |
| P-006 | Cooler Cyclone | 1 | 7,500 | 7,500 | 2,500/750 | 10,750 |  |

# Estimate Worksheet

PROJECT DNRC GRANT # 467-811

**EAGLE ENERGY SYSTEMS**
North 1322 Post Street
Spokane, Washington 99201

| | DESCRIPTION | QUANTITY | COST<br>UNIT PRICE | COST<br>AMOUNT | LABOR-MATERIAL | TOTAL COST IN PLACE | REMARKS |
|---|---|---|---|---|---|---|---|
| S-014 | Truck Scales | 1 | 24,850 | . 24,850 | 10,000/3,500 | 38,350 | |
| E-002 | Electrical Switchgear | 1 | 120,000 | 120,000 | 90,000/75,000 | 285,000 | |
| E-004 | Transformer | 1 | 40,000 | 40,000 | 5,000/7,500 | 52,500 | |
| N-002 | Truck Dumper | 1 | 27,500 | 27,500 | 10,000/5,000 | 42,500 | |
| | Building | 1 | 150,000 | 150,000 | 50,000/30,000 | 230,000 | |
| | SUB TOTAL | | 3,075,866 | 3,168,566 | 1,153,025/ | 4,058,406 | |
| | | | | | 240,575 | | |
| | | | | | | | |
| | ENGINEERING | | | | | 408,162 | |
| | CONTINGENCY | | | | | 140,000 | |
| | TOTAL | | | | | 4,606,568 | |
| | | | (15 A @ $1200/A) Land | | | 18,000 | |
| | | | | | | 4,624,568 | |
| | | | | | | x .7 | Debt Financed |
| | | | | | | 3,237,198 | |
| | | | Const. Period Interest | | | 231,010 | |
| | | | Loan Origination Fee | | | 173,410 | |
| | | | | | Total Debt | $3,641,618 | |
| | | | | | | | |
| | | Monthly Payment - 10 Years @ 15% | | | | $ 58,752 | |

# MARKETING

## 9.1 GENERAL

Two products would be produced at the proposed Eureka facility.

1. Approximately 65,000 tons of pelletized biomass fuel annually (producing 70% of year).
2. Approximately 11,100,000 kw hours of electricity.

Pellets:

To sustain a production of 65,000 tons per year (70% of year), it is felt that 2 to 3 "anchor" contracts for pellets would be necessary, each consuming approximately 10,000 tons annually. Facilities requiring these quantities of fuel would be large institutions or commercial/ industrial entities. The balance of production would be marketed to light commercial (such as greenhouses) and residential consumers. Our investigation and past experience in the industry indicates that residential and light commercial marketing (consumers of between 5 and 1,000 tons per year) would be most effectively accomplished through use of existing solid fuel dealers and supply networks and/or grain dealers. This is because both have existing capability of handling and distributing the pellet fuel. Hauling of pellets from facility to distribution points can then be accomplished in the most economical manner, by large-capacity truck or rail car. Larger consumers (1,000 to 10,000 tons per year) would easily be serviced by the same large-capacity transport vehicles, since these facilities generally have large volume fuel storages on site.

The following table expands on these markets, and lists some of the likely large "anchor" consumers in the market area.

## RESIDENTIAL

Primary marketing thrust to residential users would be centered around "older" homes with existing solid fuel boilers, pellet burning devices retrofit to airtight wood stoves (Corbin, Inc.) and new equipment such as is produced by Stokermatic, Wilburt and PMC.

## COMMERCIAL

Primary commercial customers would include users of heat for drying such as asphalt plants, agricultural dehydration plants, mines, greenhouses and gasahol plants. The most immediate prospects would include:

- W.R. Grace Mine - Libby
- St. Regis - Libby
- Pack Asphalt - Kalispell
- Plumb Creek - Columbia Falls
- Stauffer Chemical - Butte

## INSTITUTIONAL

Would include universities, hospitals, schools and city, county and state facilities.

### Electricity:

Based on contracts with Bonneville Power Administration, a power purchase price of $0.037/KWH has been established for the output of the facility. A 6,000 hour production year has been assumed, at an average output of 1850 KW. This results in an annual market production of 11,100,000 KW/HRS.

## 9.2 FUEL COST COMPARISON, EUREKA MARKETING AREA

| LOCATION | OIL | NATURAL GAS | ELECTRICITY | COAL | PRES-TO-LOG | WOOD PELLETS |
|---|---|---|---|---|---|---|
| Eureka | $1.13 Gal.<br>$8.07/MMBTU | N/A | Res. $.036/KWH<br>$10.54/MMBTU<br>Com. $.036/KWH<br>$10.54/MMBTU | N/A | N/A | @ $80.00/Ton<br>$5.00/MMBTU |
| Kalispell | $1.14/Gal.<br>$8.14/MMBTU | Res. $.468/Therm<br>Com. $.468/Therm | Res. $.053 KWH<br>$15.52.MMBTU<br>Com. $.0435 KWH<br>$12.74/MMBTU | N/A | N/A | $80.00/Ton<br>$5.00/MMBTU |
| Missoula | @ $1.14/Gal.<br>$8.14/MMBTU | Res. $.467/Therm<br>Com. $.467/Therm<br>$4.67/MMBTU | Res. $.029/KWH<br>$8.49/MMBTU<br>Com. $.064/KWH<br>$18.74/MMBTU | Usage not allowed within city limits. | @ $128.40/Ton<br>$8.02/MMBTU | @ $80.00/Ton<br>$5.00/MMBTU |

All energy costs current as of October 1982.

NOTE:

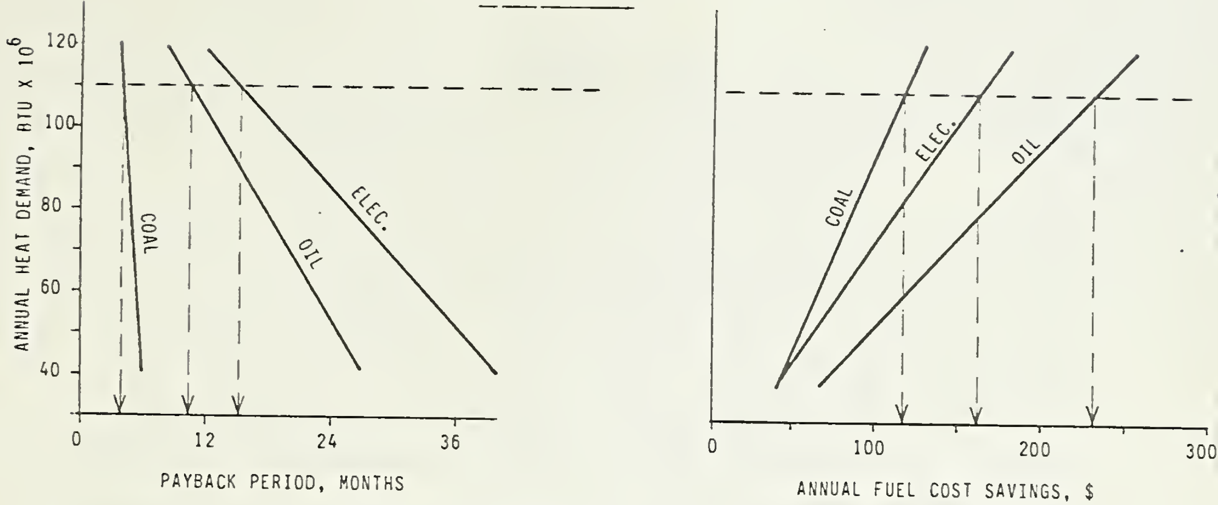
Gas - 1 Therm - 1000,000 BTU
Electricity - 1 KWH - 3,415 BTU
Coal - 1 Ton - 20 MMBTU
Oil - 1 Gal. - 140,000 BTU
Pres-to-Log - 1 Ton - 16 MMBTU
Wood Pellet - 1 Ton - 16 MMBTU

## 9.3 PAYBACK ANALYSIS

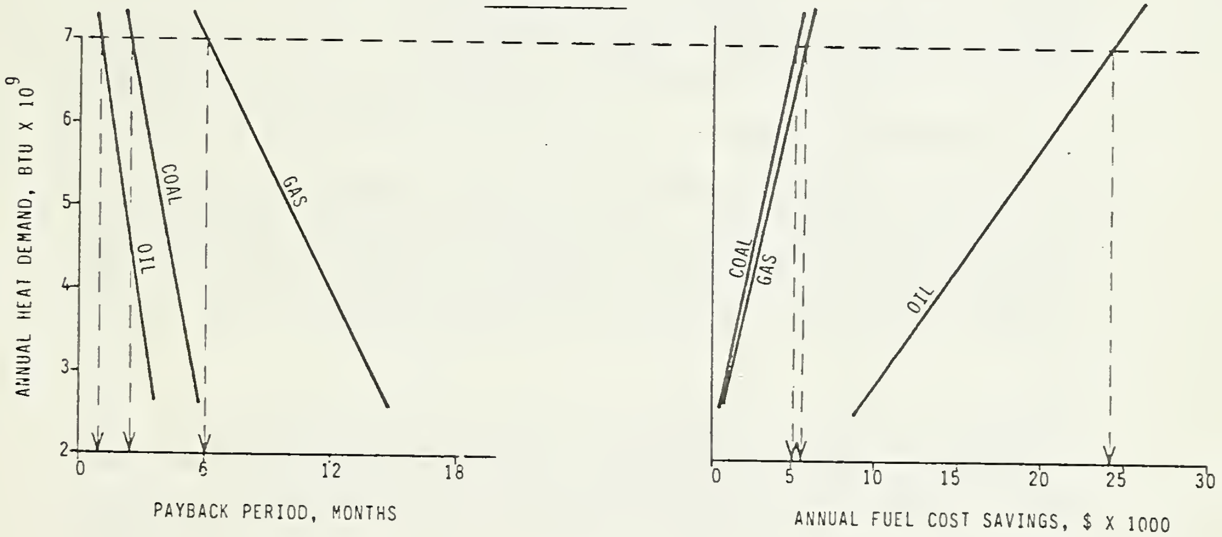
The following graphs and explanatory notes have been developed to serve as a rough guide to determining payback time and annual fuel cost savings assuming conversion costs for certain types of facilities. These graphs are based on the current fuel costs listed in Section 9.2.

# WOOD PELLET CONVERSION PAYBACK AND SAVINGS

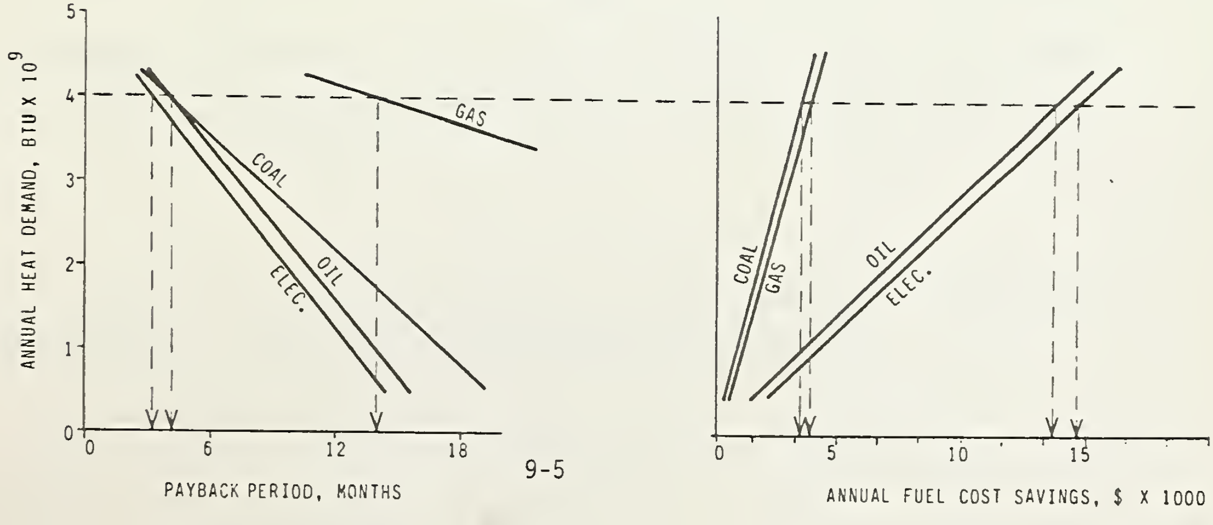
## RESIDENTIAL



## COMMERCIAL



## INSTITUTIONAL



## NOTES TO GRAPHS

In order to arrive at a simple and accurate representation of payback period and annual fuel cost savings, assumptions have been made as to typical retrofit situations in each of the 3 categories: residential, institutional and commercial. These assumptions are admittedly narrow in scope. This is because the first market for pellet fuel will consist almost entirely of conversions, and the first conversions will take place where relatively little new equipment is required. It will also be noted that the retrofit cost assumed in each of the 3 categories is constant, without regard to the amount of energy usage. Where retrofits are concerned, this is valid since labor is one of the chief retrofit cost components, and the amount of time required on our "typical" retrofit job may well be the same whether the device produces 3 million or 8 million btus per hour of heat.

In spite of the restrictions imposed by these assumptions, they are completely valid for a large number of potential customers, the first market" referred to previously.

The following "typical retrofit" cost assumptions are valid for any community where there are many older homes, schools, hospitals, greenhouses, etc.

### Typical Retrofit Cost

Residential: Assumes older coal furnace and stoker are still in place. Work required includes replacing stoker parts, "leak-proofing" a storage area, tuning furnace, etc.

Average Cost: $250.00

Institutional (eg., school or hospital): Assumes older coal stoker boiler was converted to oil or natural gas, that stoker parts are required, storage is still available over-fire air needs to be installed, some new controls are necessary.

Average Cost $4,000.00

Or, existing coal stoker boiler needs some modification and "tuning".

Average Cost $1,000.00

Commercial (eg., greenhouse): Same as institutional, above.

To arrive at usage quantity assumptions, Ashrae data was used (ref: Ashrae Fundamentals, 1977). The horizontal dashed lines on the graphs represent the annual usage quantity assumed.

Example of use of charts: Assume a green house has a main boiler which was converted to natural gas. As per the retrofit requirement assumptions (this page), the cost to convert is estimated at $4,000.00. Assume the annual gas consumption was 60,000 therms on average, or 6 x $10^9$ Btu (1 therm = 100,000 Btu).

From the charts, (pg. 2) read across the page @ 6 x $10^9$ Btu to intersect the lines marked "Gas". Read down from these intersections to read PAYBACK PERIOD, and ANNUAL FUEL COST SAVINGS, 8 months and $4,500 / yr, respectively.

# APPENDICES

# APPENDIX A

# COMPUTER PROGRAM

```
0 SYSTEM"FORMS P=168,L=166,W=80"
0 INPUT"AMBIENT TEMPERATURE";T1
0 IF T1<0 OR T1>100 THEN PRINT"T1 MUST BE BETWEEN 0F AND 100F":GOTO 20
0 INPUT"TURBINE INLET TEMPERATURE";T3
0 IF T3<1300 OR T3>1600 THEN PRINT"T3 MUST BE BETWEEN 1300F AND 1600F":GOTO 4

0 INPUT"ALTUTIDE";AL
0 IF AL<0 OR AL> 10000 THEN PRINT"THIS ALTITUDE BEYOND PROGRAM LIMITS":GOTO 6

0 INPUT"TURBINE INLET PRESSURE DROP(INCHES OF WATER)";P1D
0 CM=3.15728E-3-9.99495E-6*T1-5.34629E-9*T1*T1
00 CB=5.84401-0.134256*T1+9.86493E-5*T1*T1
10 CR=CM*T3+CB
20 S2=(T1+460.)*(CR↑.286)-460.
30 ZC=80.8+.048425*T1-7.44842E-5*T1*T1
40 T2=(100.*(S2-T1))/ZC+T1
50 P2=CR*14.7
60 S4=(T3+460.)/((P2/14.7)↑.286)-460.
70 T4=T3-.915*(T3-S4)
80 XM=41.0372-.0359553*T1-1.64472E-4*T1*T1
90 WC=XM*.2497*(T2-T1)
00 WT=XM*.2497*(T3-T4)
10 WN=WT-WC
20 KW=WN*3600.*.916/3413.
30 D1=.999836-3.62636E-5*AL+4.99998E-10*AL*AL
40 L4PI=4.35303+1.14522E-3*KW-2.688818E-7*KW↑2+4.84824E-11*KW↑3
50 L1PI=4.319+3.26745E-3*KW-7.15944E-8*KW↑2+2.626E-11*KW↑3
60 KAL=KW*(1-D1)
70 KIL=L1PI*P1D
80 KOL=(T1/31+9.104)*L4PI
90 LPRINT:LPRINT:LPRINT
00 KN=KW-KAL-KIL-KOL
10 LPRINT CHR$(31)
20 LPRINT TAB(5)"COMPUTER SIMULATION"
30 LPRINT CHR$(30)
40 LPRINT TAB(10)"INDIRECTLY HEATED GAS FIRED TURBINE"
50 LPRINT TAB(10)"SOLAR CENTAUR G5400 GENERATOR PACKAGE"
60 LPRINT:LPRINT:LPRINT
70 FOR J=1 TO 60:LPRINT"*";:NEXT
80 LPRINT:LPRINT
90 LPRINT "INPUT DATA:"
00 LPRINT
10 LPRINT"AMBIENT TEMPERATURE (F)";:LPRINTTAB(40)"=  ";T1
20 LPRINT"ALTITUDE ABOVE SEA LEVEL (FT)";:LPRINT TAB(40)"=  ";AL
30 LPRINT"TURBINE INLET TEMPERATURE SETTING(F)";:LPRINT TAB(40)"=  ";T3
40 LPRINT"PRESSERE LOSS ON ENGINE INLET(IN OF H2O)";:LPRINT TAB(40)"=  ";P1D
50 LPRINT:LPRINT:LPRINT
60 LPRINT "OUTPUT DATA FOR GENERATER SYSTEM"
70 LPRINT
80 LPRINT"COMPRESSOR RATIO";:LPRINT TAB(40)"=  ";CR
90 LPRINT"IDEAL TEMPERATURE AT COMP EXIT (F)";:LPRINT TAB(40)"=  ";S2
00 LPRINT"ACTUAL TEMPERATURE AT COMP. EXIT (F)";:LPRINT TAB(40)"=  ";T4
0 LPRINT"PRESSURE AT COMP. EXIT (psi)";:LPRINT TAB(40)"=  ";CR*14.7
```

```
520 LPRINT"PRESSURE DROP THRU HEAT EXCHANGER (psi)";:LPRINT TAB(40)"=  ";(-P2+
CR*14.7)
530 LPRINT"PRESSURE AT TURBINE INLET (psi)";:LPRINT TAB(40)"=  ";P2
540 LPRINT"IDEAL TEMPERATURE AT TURBINE EXIT (F)";:LPRINT TAB(40)"=  ";S4
550 LPRINT"ACTUAL TEMPERATURE AT TURBINE EXIT (F)";:LPRINT TAB(40)"=  ";T4
560 LPRINT"ADIABATIC COMPRESSOR EFFICIENCY";:LPRINT TAB(40)"=  ";ZC
570 LPRINT"ADIABATIC TURBINE EFFICIENCY";:LPRINT TAB(40)"=   91.5"
580 LPRINT"MASS FLOW RATE THRU ENGINE (LB/SEC)";:LPRINT TAB(40)"=  ";XM
590 LPRINT"WORK OF COMPRESSION (HORSEPOWER)";:LPRINT TAB(40)"=  ";WC*1.414
600 LPRINT"TURBINE WORK (HORSEPOWER)";:LPRINT TAB(40)"=  ";WT*1.414
610 LPRINT"NET WORK AVAILABLE AT SHAFT (HORSEPOWER)";:LPRINT TAB(40)"=  ";WN*1
.414
620 LPRINT
630 LPRINT"POWER GENERATED AFTER GENERATOR AND"
640 LPRINT"GEAR LOSSES AT SEA LEVEL (KW)";:LPRINT TAB(40)"=  ";KW
650 LPRINT
660 LPRINT"POWER LOSS DUE TO ALTITUDE (KW)";:LPRINT TAB(40)"=  ";KAL
670 LPRINT"POWER LOSS DUE TO INLET PRES. LOSS(KW)";:LPRINT TAB(40)"=  ";KIN
680 LPRINT"POWER LOSS DUE TO BACKPRESSURE (KW)";:LPRINT TAB(40)"=  ";KOL
690 LPRINT
700 LPRINT"TOTAL POWER GENERATED (KW)";:LPRINT TAB(40)"=  ";KN
710 LPRINT:LPRINT
720 FOR I=1 TO 60:LPRINT"*";:NEXT
730 LPRINT
740 FORI=1TO16:LPRINT:NEXT
750 C=0
760 T5=T3+225
770 XH=XM*1.1
780 T=T4-15
790 GOSUB 4000
800 H4=HA
810 T=T2
820 GOSUB 4000
830 H2=HA
840 T=T3
850 GOSUB 4000
860 H3=HA
870 T=T5
880 GOSUB 3000
890 GOSUB 4000
900 H5=(XM*HA)/XH+(XH-XM)*HC/XH
920 FR=(XM*(H5-H4))/(8160-H5*2.2)
930 X=XM+2.2*FR
940 IF ABS(X-XH)<.05 THEN C=1
950 XH=X
960 GOTO 900
970 BC=(H3-H2)*XM
975 BC=BC/.9
980 H6=-BC/XH+H5
990 T=T2
1000 DT=100.
1010 GOSUB 3000
1020 GOSUB 4000
1030 HT=XM*HA/XH+(XH-XM)*HC/XH
1040 IF HT<H6 THEN T=T+DT:GOTO 1010
1050 DT=DT/2
```

```
0060 IF DT .5 THEN GOTO 1080
0070 T=T-DT:GOTO 1010
0080 T6=T
0090 LPRINT:LPRINT:LPRINT:LPRINT
0100 FOR I=1 TO 60:LPRINT"*";:NEXT
 110 LPRINT:LPRINT
0120 LPRINT"OUTPUT DATA FOR COMBUSTER AND HEAT EXCHANGER"
0130 LPRINT
 140 LPRINT"TEMPERATURE ENTERING HEAT EXCHANGER(F)";:LPRINT TAB(50)"= ";T5
0150 LPRINT"TEMPERATURE LEAVING  HEAT EXCHANGER(F)";:LPRINT TAB(50)"= ";T6
0152 LPRINT"TEMPERATURE SEC. & TERTIARY AIR(F)";:LPRINT TAB(50)"= ";T4-15.
0160 LPRINT"ENTHALPY OF GAS ENTERING H.E. (BTU/LB)";:LPRINT TAB(50)"= ";H5
 170 LPRINT"ENTHALPY OF GAS LEAVING  H.E. (BTU/LB)";:LPRINT TAB(50)"= ";H6
 175 LPRINT"ENTHALPY OF AIR LEAVING COMPRESSOR(BTU/LB)";:LPRINTTAB(50)"= ";H2
 176 LPRINT"ENTHALPY OF AIR ENTERING TURBINE(BTU/LB)";:LPRINT TAB(50)"= ";H3
 177 LPRINT"HEAT TRANSFERED TO TURBINE AIR(BTU/HR)";:LPRINT TAB(50)"= ";BC*360
0.
 180 LPRINT"ESTIMATED HEAT LOSS TO SURROUNDINGS(BTU/HR)";:LPRINT TAB(50)"= ";.
7*BC*3600.
 190 LPRINT"MASS FLOW THRU HEAT EXCHAMGER(LBS/SEC)";:LPRINT TAB(50)"= ";XH
 200 LPRINT"PRIMARY AIR MASS FLOW RATE(LBS/SEC)";:LPRINT TAB(50)"= ";FR*1.2
 210 LPRINT"SECONDARY AIR MASS FLOW RATE(LBS/SEC)";:LPRINT TAB(50)"= ";FR*6.8
 220 LPRINT"TERTIARY AIR MASS FLOW RATE(LBS/SEC)";:LPRINT TAB(50)"= ";XM-6.8*F
R
 230 LPRINT"FUEL RATE-WOOD @15% MOISTURE(TONS/HR)";:LPRINT TAB(50)"= ";FR*2
 231 T=T1
 232 GOSUB 4000
 240 LPRINT"HEAT CONTENT OF LEAVING GAS STREAM(BTU/HR)";:LPRINT TAB(50)"= ";XH
(H6-HA)*3600
 241 FF=2*FR*16E+6
 242 E0=KN*3413/FF
 243 E5=((KN*3413)+((H6--HA)*XH*1800))/FF
 244 E1=((KN*3413)+((H6-HA)*XH*3600))/FF
 245 LPRINT"CYCLE EFFICIENCY USING 0% OF EXIT GAS ENERGY";:LPRINT TAB(50)"= ";
0*100.
 246 LPRINT"CYCLE EFFICIENCY USING 50% OF EXIT GAS ENERGY";:LPRINT TAB(50)"= "
E5*100.
 247 LPRINT"CYCLE EFFICIENCY USING 100% OF EXIT GAS ENERGY";:LPRINT TAB(50)"=
;E1*100
 250 LPRINT:LPRINT
 260 FOR I=1 TO 60:LPRINT"*";:NEXT
 270 LPRINT
 010 LPRINT CHR$(27);CHR$(28)
 020 LPRINTTAB(16)CHR$(245)
 030 LPRINTTAB(16)CHR$(245);" ";:LPRINTUSING"##.##";2*FR;:LPRINT" TONS/HR WOOD
AT 15% MC"
 040 LPRINT TAB(16)CHR$(245)
 050 LPRINTTAB(16)CHR$(245);" ";:LPRINTUSING"##.##";1.2*FR;:LPRINT" LBS/SEC PR
MARY AIR"
 060 FOR I=1TO2:LPRINTTAB(16)CHR$(245):NEXT
 070 LPRINTTAB(16)CHR$(245);"    ";CHR$(235);:FOR I=1TO19:LPRINTCHR$(231);:NEXT
PRINTCHR$(236)
 080 FORI=1TO3:LPRINTTAB(16)CHR$(245);"    ";CHR$(233);:LPRINTTAB(40)CHR$(234):
EXT
```

```
2090 LPRINTTAB(16)CHR$(246);CHR$(241);CHR$(241);">";CHR$(233);"      COMBUSTER
    ";CHR$(234);:FORI=1TO13:LPRINTCHR$(241);:NEXT:LPRINT">";CHR$(242)
2100 LPRINTTAB(20)CHR$(233);:LPRINTTAB(40)CHR$(234);"    ↑";:LPRINTTAB(55)CHR$(
245)
2110 FORI=1TO2:LPRINTTAB(20)CHR$(233);:LPRINTTAB(40)CHR$(234);"    ";CHR$(245);
:LPRINTTAB(55)CHR$(245)
2120 NEXT
2130 LPRINTTAB(20)CHR$(237);:FORI=1TO19:LPRINTCHR$(232);:NEXT:LPRINTCHR$(238);
"    ";CHR$(245);TAB(55);CHR$(245)
2140 LPRINTTAB(33);"↑";TAB(44)CHR$(245);TAB(55)CHR$(245)
2150 FORI=1TO12
2160 IFI=3THENLPRINTTAB(33)CHR$(245);" ";:LPRINTUSING"####";T4-15;:LPRINTCHR$(
166);"F";TAB(44)CHR$(245);TAB(55)CHR$(245):NEXT I
2170 IFI=6THENLPRINTTAB(33)CHR$(245);:LPRINTUSING"###.##";6.8*FR;:LPRINTTAB(44
)CHR$(245);:LPRINTUSING"###.##";XM-8*FR;:LPRINTTAB(55)CHR$(245):NEXT I
2180 IFI=8THENLPRINTTAB(33)CHR$(245);" LBS/SEC";TAB(44)CHR$(245);" LBS/SEC";TA
B(55)CHR$(245):NEXT I
2190 IFI=10THENLPRINTTAB(33)CHR$(245);" SEC. AIR";TAB(44)CHR$(245);" TERT. AIR
";TAB(55)CHR$(245):NEXT I
2200 LPRINTTAB(33)CHR$(245);TAB(44)CHR$(245);TAB(55)CHR$(245):NEXT I
2210 LPRINTTAB(33)CHR$(244);:FORI=1TO9:LPRINTCHR$(241);:NEXT:LPRINT">";CHR$(24
7);TAB(55)CHR$(245);:LPRINTUSING"###.##";XH;:LPRINT" LBS/SEC"
2220 FORI=1TO3
2230 IFI=3THENA=118ELSEA=245
2240 IF I=2THENLPRINTTAB(33)CHR$(245);TAB(55)CHR$(245);:LPRINTUSING"#####";T5;
:LPRINTCHR$(166);"F"
2250 LPRINTTAB(33)CHR$(245);TAB(55)CHR$(A)
2260 NEXT
2270 LPRINTTAB(33)CHR$(245);TAB(50)CHR$(235);:FORI=1TO9:LPRINTCHR$(231);:NEXT:
LPRINTCHR$(236)
2280 LPRINTTAB(33)CHR$(246);CHR$(241);CHR$(241);CHR$(253);CHR$(239)CHR$(239);C
HR$(239);CHR$(239);CHR$(239);CHR$(251);TAB(50)CHR$(233);TAB(60)CHR$(234)
2290 LPRINTTAB(23);:LPRINTUSING"##.##";XM;:LPRINT" LBS/SEC";TAB(37)CHR$(253);C
HR$(239);CHR$(239);CHR$(239);CHR$(251);TAB(50)CHR$(233);TAB(60)CHR$(234)
2300 LPRINTTAB(38)CHR$(253);CHR$(239);CHR$(251);"<";:FORI=1TO8:LPRINTCHR$(241)
;:NEXT:LPRINTCHR$(233);TAB(60)CHR$(234)
2310 A=T3
2320 FORI=1TO7
2330 IFI=1THENLPRINTTAB(27);:LPRINTUSING"####";T4;:LPRINTCHR$(166);"F";
2340 LPRINTTAB(39)CHR$(245);
2350 IFI>2THENA=T2
2360 IFI=2ORI=6THENLPRINTUSING"#######";A;:LPRINTCHR$(166);"F";
2370 LPRINTTAB(50)CHR$(233);
2380 IFI=3THENLPRINT"  HEAT    ";CHR$(234);TAB(62);.1*BC*3600:NEXT I
2390 IFI=5THENLPRINT"EXCHANGER";CHR$(234);"  BTU/HR LOSS":NEXT I
2400 LPRINTTAB(60)CHR$(234):NEXT
2410 LPRINTTAB(38)CHR$(252);CHR$(239);CHR$(254);:FORI=1TO8:LPRINTCHR$(241);:NE
XT:LPRINT">";CHR$(233);TAB(60)CHR$(234)
2420 LPRINTTAB(37)CHR$(252);CHR$(239);CHR$(239);CHR$(239);CHR$(254);TAB(50)CHR
$(233);TAB(60)CHR$(234)
2430 LPRINTTAB(32)CHR$(240);CHR$(241);CHR$(241);">";CHR$(252);CHR$(239);CHR$(2
39);CHR$(239);CHR$(239);CHR$(239);CHR$(254);TAB(50)CHR$(233);TAB(60)CHR$(234)
2440 LPRINTTAB(32)CHR$(245);TAB(39)CHR$(245);TAB(50)CHR$(237);:FORI=1TO9:LPRIN
TCHR$(232);:NEXT:LPRINTCHR$(238)
```

```
2450 FORI=1TO3
2460 IFI=1THENLPRINTTAB(23);:LPRINTUSING"###";T1;:LPRINTCHR$(166);"F";
2470 IFI=3THENLPRINTTAB(17);:LPRINTUSING"#####";AL;:LPRINT" FT ASL";
2480 LPRINTTAB(32)CHR$(245);TAB(39)CHR$(245);TAB(55)CHR$(245):NEXT
2490 LPRINTTAB(32)CHR$(245);TAB(36)CHR$(235);:FORI=1TO5:LPRINTCHR$(231);:NEXT:
LPRINTCHR$(236);TAB(55)CHR$(245)
2500 FORI=1TO8
2510 IFI>4THENGOTO2550
2520 IFI=1THENLPRINTTAB(17);:LPRINTUSING"##.##";P1D;:LPRINT" IN. H20";
2530 IFI=3THENLPRINTTAB(20);"PRES. DROP";
2540 LPRINTTAB(32)CHR$(245);
2550 LPRINTTAB(36)CHR$(233);
2560 IFI=3THENLPRINT" GEN";
2570 IFI=5THENLPRINTUSING"#####";KN;
2580 IFI=7THENLPRINT"  KW";
2590 LPRINTTAB(42)CHR$(234);TAB(55)CHR$(245):NEXT
2600 LPRINTTAB(36)CHR$(237);:FORI=1TO5:LPRINTCHR$(232);:NEXT:LPRINTCHR$(238);T
AB(55)"v"
2610 LPRINT:LPRINTTAB(52);:LPRINTUSING"####";T6;:LPRINTCHR$(166);"F"
2612 LPRINT:LPRINTTAB(49);XH*(H6-HA)*3600;"BTU/HR"
2613 SYSTEM"FORMS T"
2614 LPRINTCHR$(27);CHR$(54)
2650 END
3000 HC=-22.632+.246478*T+1.09939E-5*T*T
3010 RETURN
4000 T=T+460.
4010 HA=2.43099+.228405*T+9.34299E-6*T*T+2.91538E-9*T↑3
4015 T=T-460
4020 RETURN
```

# APPENDIX B

# STEADY-STATE ANALYSIS OF A WOOD-BURNING, INDIRECTLY HEATED GAS TURBINE GENERATOR SYSTEM

## FINAL REPORT

JAYCOR Contract 5214-00

Prepared by:

James. R. Carlson, PE
Terry L. Greenlee, PE

Submitted to:

Eagle Energy Systems
P. O. Box 3452
Missoula, Montana 59801

October 27, 1980

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# 1. INTRODUCTION

This report summarizes an analysis that was conducted by JAYCOR's Power Engineering Group for Eagle Energy Systems. A proposed wood-burning, indirectly heated gas turbine generator system, shown in Figure 1, was analyzed to determine feasibiliy, design point performance, and design point sensitive.

Feasibility was examined on the basis that components such as the gas turbine, heat exchanger, and combustor were commonly available and could meet the requirements of the specified design.

Design point performance and sensitivity were assessed by performing a static heat balance for the proposed system at two likely operating conditions.

Section 2 describes the assumptions that were made for system components and heat balance analyses. The section concludes with a discussion of some sensitivity design issues that should be considered in an overall assessment of the system's credits.

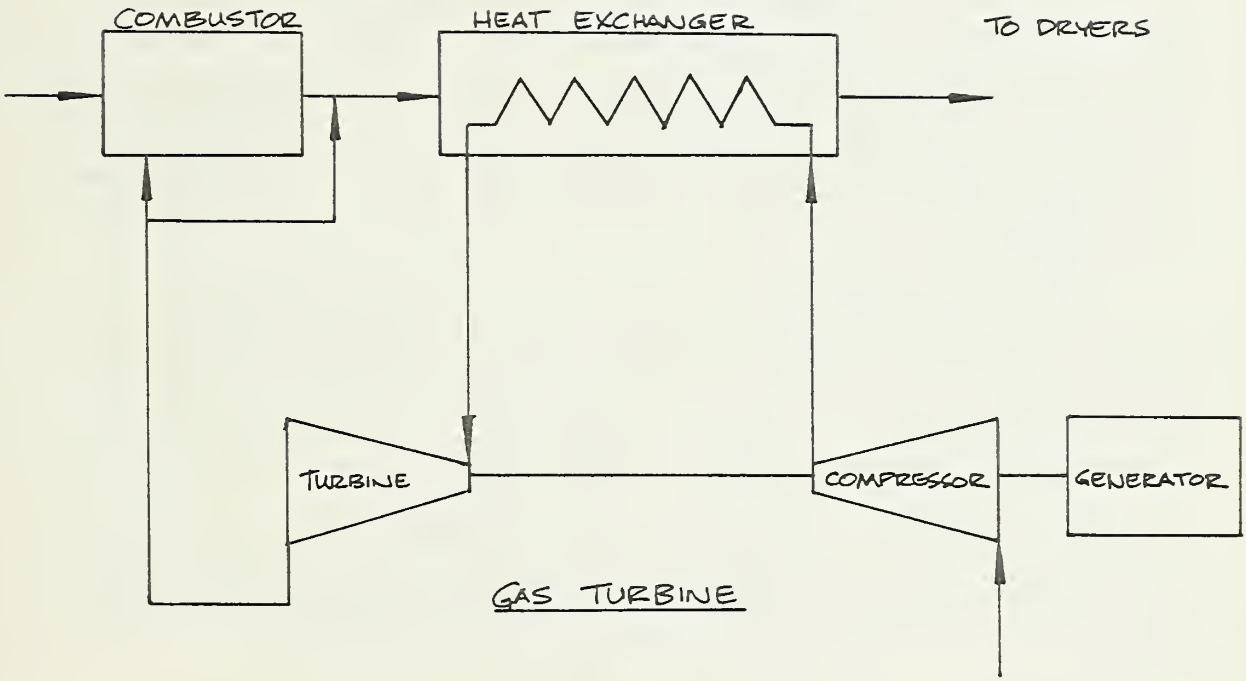


FIGURE 1 SYSTEM SCHEMATIC

## 2. TECHNICAL DISCUSSION

The proposed system consists of (1) a wood-burning combustor, supplied by Applied Combustion Technology, (2) a heat exchanger, supplied by Coaltech Farrier, and (3) a CENTAUR gas turbine, supplied by SOLAR Turbines International. Design data for these components was provided by each manufacturer. This data is shown in Appendix A.

Using the data provided, a static heat balance was conducted for the proposed system at ambient temperatures of $28^{o}$F and $59^{o}$F. All calculations were carried out assuming process flows were ideal gas, with no heat losses. Compressor inlet losses were assumed to be zero. The turbine will operate with a back pressure of 20 inches of water. Table 1 shows a summary of the system parameters that incorporates the effects of the component design data and assumptions.

Figures 2 and 3 show heat balances for the two ambient temperatures. No attempt was made to determine the amount of fuel (wood or other) required. Figure 2 shows the net output of the turbine is 1731.12 kW at $59^{o}$F. Figure 3 shows that net output of the turbine is 2007.8 kW at $28^{o}$F. The hand calculations supporting these heat balances are provided in Appendix B.

During the course of this analysis, certain parameters have been observed to have a significant effect upon overall cycle performance. Three major ones are: ambient temperature, turbine inlet temperature, and turbine back pressure.

Ambient temperature effects are illustrated by the two heat balances.

Turbine inlet temperature variations produce variations in turbine output power. The sensitivity of output power for $^{o}$F is 3.25 kW/$^{o}$F. The sources of such variation can be fouled heat exchanger surface or control errors induced by temperature sensor inaccuracies.

Turbine back pressure variations are also important in determining turbine power output. For the $59^{o}$F ambient case, the sensitivity of output power to back pressure is 6.0 kW/inch/$H_2O$. Sources of turbine back pressure are heat exchanger fouling and unnecessary gas ducting.

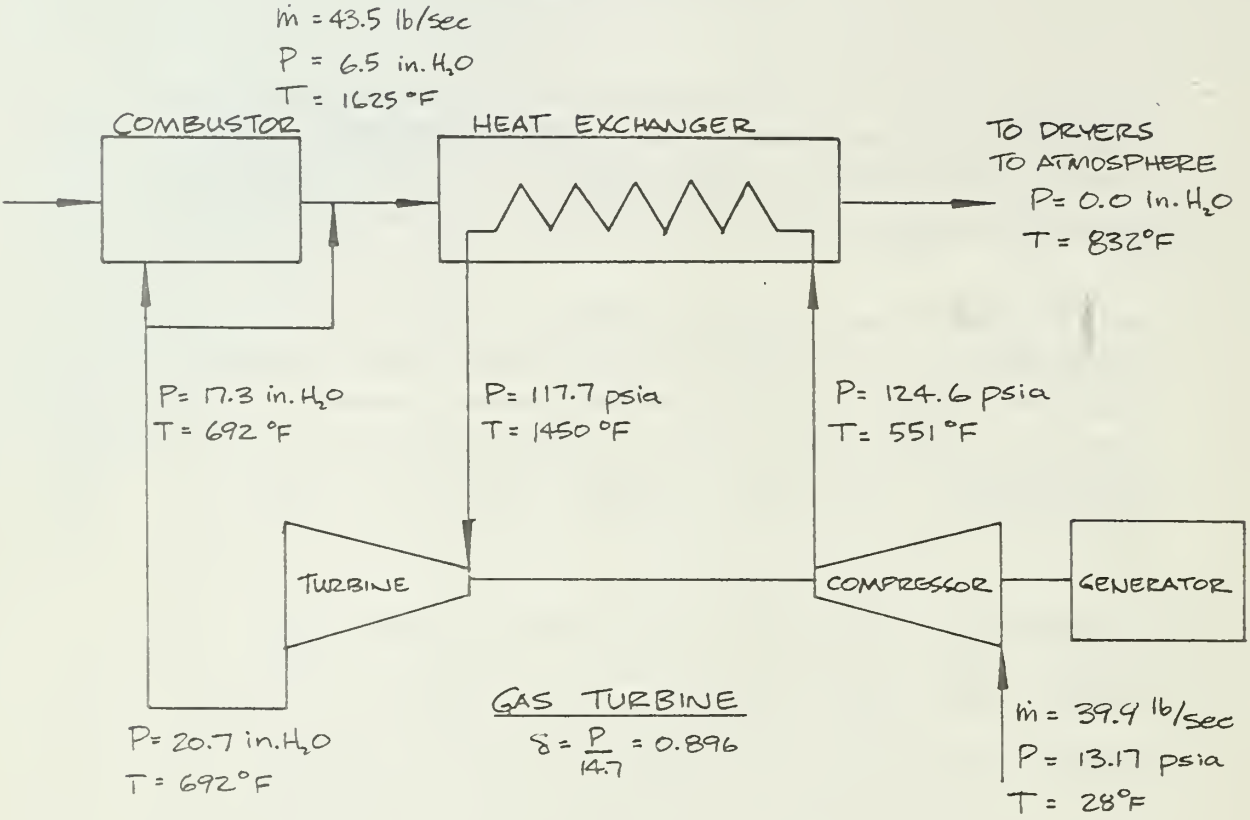
| SYSTEM PARAMETERS | AMBIENT TEMPERATURE 59°F | AMBIENT TEMPERATURE 28°F |
|---|---|---|
| Pressure Drop (in. $H_2O$) | | |
| Heat Exhanger | 6 | 6.5 |
| Combustor | 10 | 10.8 |
| Connecting Duct | 3.1 | 3.3 |
| Turbine Flow Rate (lb/sec) | 38.35 | 39.9 |
| Heat Exchanger Outlet Temp. (°F) | 871 | 832 |
| Gross Output (KW) | 1845.8 | 2137.0 |
| Exhaust Loss (KW) | 114.6 | 129.2 |
| Net Output (KW) | 1731.2 | 2007.8 |

TABLE 1 - SYSTEM PARAMETERS

FOR

TWO AMBIENT TEMPERATURES

## FIGURE #2
## SUMMARY OF SYSTEM CONDITIONS
## AT 28°F AMBIENT



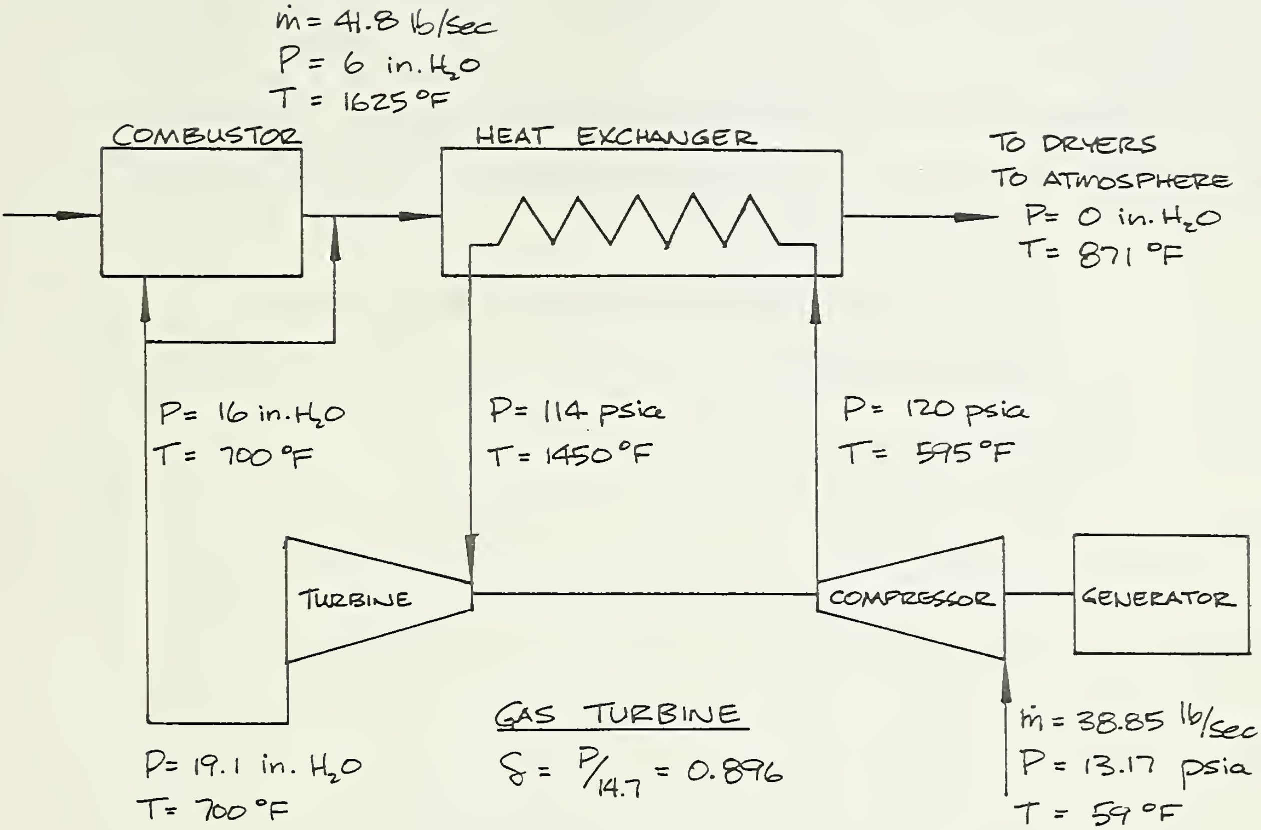
| | |
|---|---|
| GROSS OUTPUT | 2137.0 KW |
| EXHAUST LOSS | 129.2 KW |
| NET OUTPUT | 2007.8 KW |

ASSUMPTIONS

- No Inlet Losses
- Altitude = 3,000 ft (13.17 psin)
- All Gases Ideal
- No Heat Losses
- Heat Exchanger has design basis as follows:

$T_{LOG}$ = 221°F, UA = 156,000 BTU/hr-°F

## FIGURE #3
## SUMMARY OF SYSTEM CONDITIONS
## AT 59°F AMBIENT



| | |
|---|---|
| GROSS OUTPUT | 1845.8 KW |
| EXHAUST LOSS | 114.6 KW |
| NET OUTPUT | 1731.2 KW |

ASSUMPTIONS

- No Inlet Losses
- Altitude = 3,000 ft (13.17 psin)
- All Gases Ideal
- No Heat Losses

  Heat Exchanger has design basis as follows:

  $T_{LOG}$ = 221°F, UA = 156,000 BTU/hr-°F

The sensitivities just described should not be a problem if proper actions are taken during the detailed design phase of this project. Turbine inlet temperature can be adequately controlled, provided integral feedback control laws are used. Back pressure on the turbine can be held at a desired value through the use of soot blowers and good ducting design.

A more thorough analysis of this system should be conduted as the design progresses. This analysis should include:

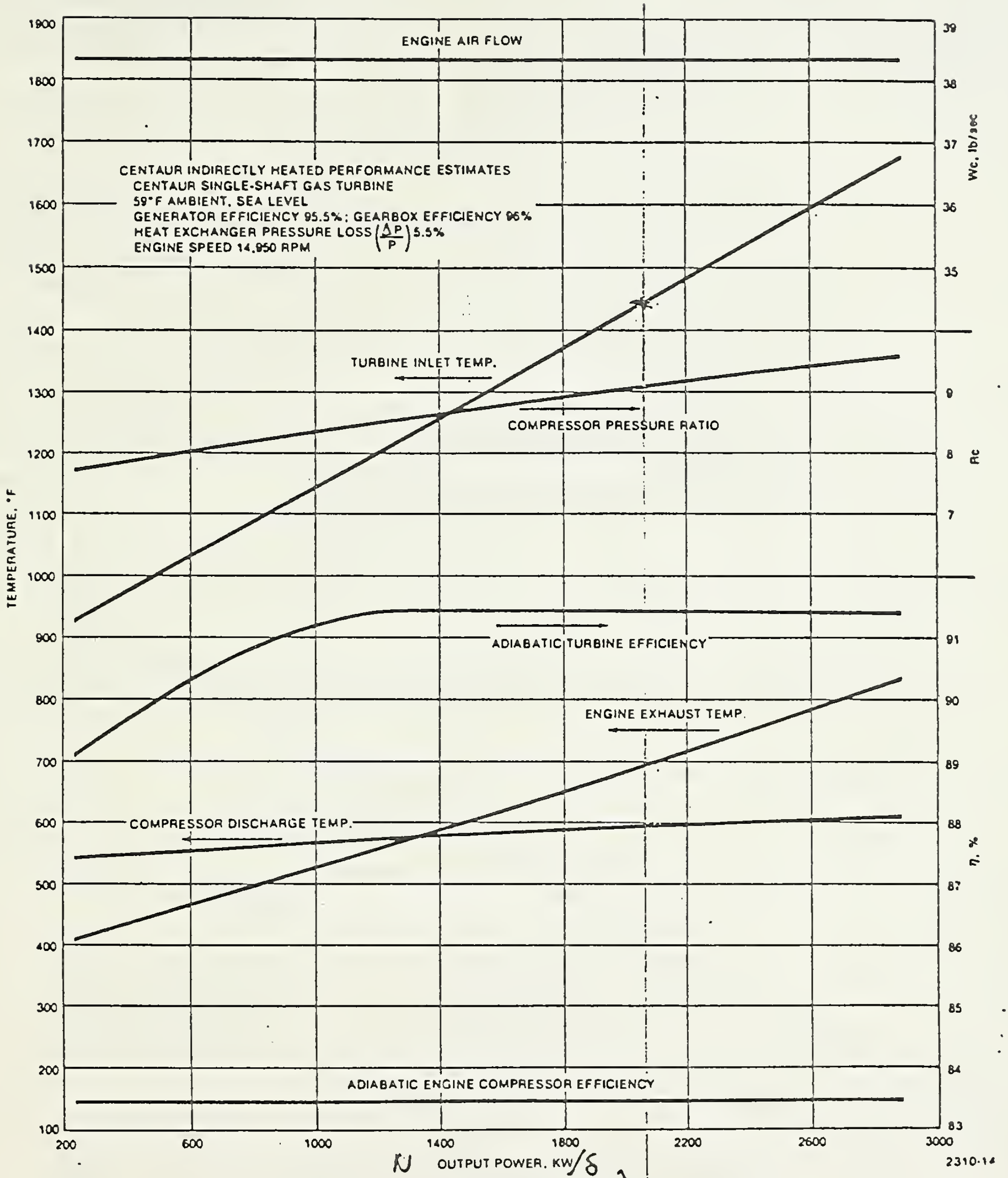
- more detailed static heat balances for system components.
- dynamic analyses for the system to determine control and protection strategies.

## 3. CONCLUSIONS

In conclusion, the proposed design appears feasible, and its performance would be as indicated by the two heat balances.

# APPENDIX A:

# TECHNICAL DATA ON SYSTEM COMPONENTS



KW = δN

KW/δc by J Houde 10/24

Figure 4. GS4000 Indirect Heated Output Power Estimates at 59°F

Centaur

FROM SOLAR TURBINES
DESIGN BOOK VIA. R. PELTIER
10/24/80

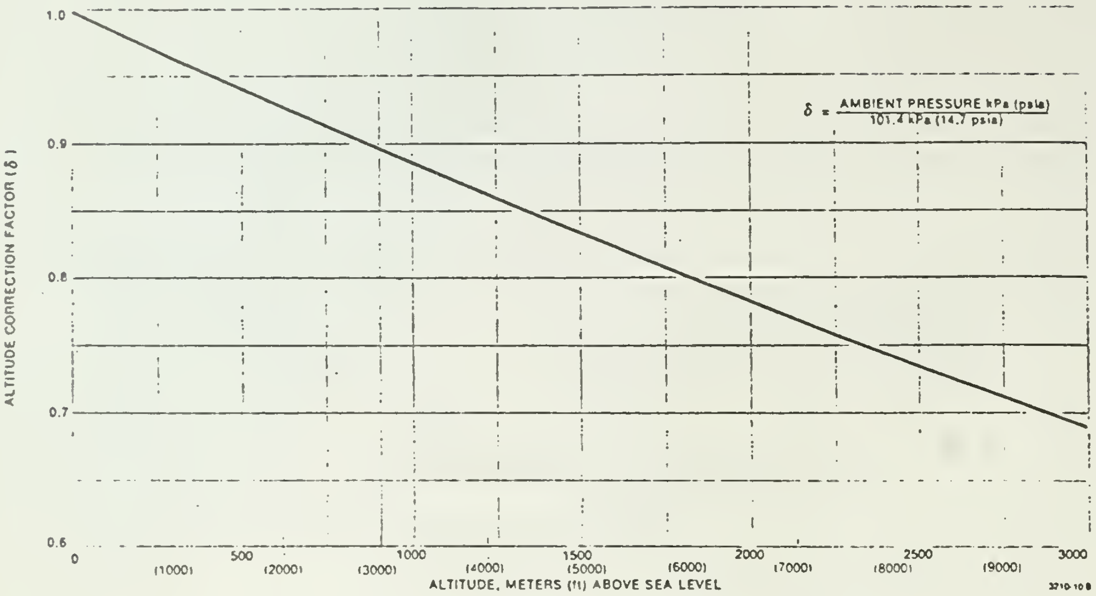


Figure 13-1. Performance Correction Factor for Altitude

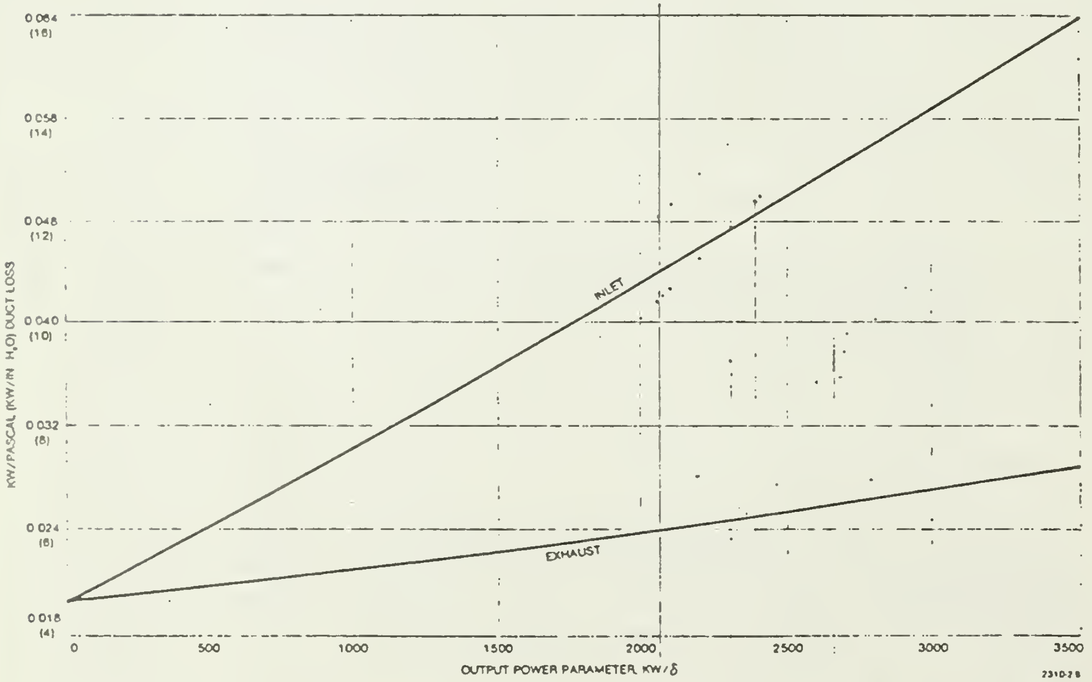


Figure 13-2. Inlet and Exhaust Power Loss

FROM SOLAR
TURBINES DESIGN BOOK
VIA R. PELTIER 10/24/80

COALTECH FARRIER

*The leader in high temperature heat exchange equipment* • Church Road & Derry Court
P.O. Box 1602
York, PA 17405
717-767-6717

August 20, 1980

Solar Division
International Harvester
2200 Pacific Highway
San Diego, California 92138

Attention: Mr. Robert Pelltier
Systems Engineer

Subject: Coaltech-Farrier Indirect Heaters for the Saturn and Centaur Engines

Reference: Your Verbal Request of August 15, 1980
Our Proposal #006H7-A

Gentlemen:

We are writing to update and correct our previous quotation of June 11, 1980 for the two size indirect heaters.

The proposed heat exchangers are designed utilizing the following data.

Saturn Engine (87% Effectiveness):

Engine Air Side

| | |
|---|---|
| Flow | 13.6 Lbs./Sec. |
| Outlet Temperature | 1,450°F |
| Inlet Temperature | 472°F |
| Inlet Pressure | 90 PSIA |
| Pressure Loss | 5 PSI |

Hot Gas Side

| | |
|---|---|
| Flow | 17.68 Lbs./Sec. |
| Gas Inlet Temperature | 1,600°F |
| Pressure Loss | 8" W. C. |

## Centaur Engine (83% Effectiveness):

### Engine Air Side

| | |
|---|---|
| Flow | 38.35 Lbs./Sec. |
| Outlet Temperature | 1,450°F |
| Inlet Temperature | 597°F |
| Inlet Pressure | 134 PSIA |
| Pressure Loss | 5 PSI |

### Hot Gas Side

| | |
|---|---|
| Flow | 41.8 Lbs./Sec. |
| Gas Inlet Temperature | 1,625°F |
| Pressure Loss | 6" W.C. |

Both heat exchangers are proposed with bare, integrally rolled finned tubing. The bundles would be enclosed within an internally insulated casing.

# APPENDIX B:

## HAND CALCULATIONS SUPPORTING THE HEAT BALANCES SHOWN IN FIGURES 2 AND 3.

# GAS TURBINE CONDITIONS

Ambient Condition @ 3,000 ft.

$T = 59°F = 519°R$

$P = 13.17$ psia (ARDC Model)

$$\delta = \frac{13.17}{14.7} = .896$$

From Solar Curve 2310-14 for the GS4000

Pressure ratio = 9.1

Compressor Outlet

$P_{CO} = 9.1 \times 13.17 = 119.85$ psi

$T_o = 595°F$

Mass Flow 38.35 lb/sec

Heat Duty to the Gas Turbine

$$Q = 38.35 \frac{\text{lb}}{\text{sec}} \; 3600 \frac{\text{sec}}{\text{hr}} \; (1450 \times .275 - 595 \times .25)$$

$Q = 34.515 \times 10^6$ BTU/hr

Exhaust Duct Pressure Drop

32" Duct with 3-90° Elbows 20 ft long

$T = 700°F = 1160°R$

$P = 13.17 + 12$ in $H_2O \times .03613 = 13.6$

$\nu = RT/P = 52.34\,(1160)/13.6 \times 144$

$\nu = 31.59 \rightarrow \rho = 0.03166$

$$A = \frac{\pi D^2}{4} = \frac{\pi (32)^2}{4 \times 144} = 5.585 \text{ ft}^2$$

$$V = \frac{M}{SA} = \frac{38.35 \text{ lb ft}^2}{\text{sec } 0.03166 \text{ lb } 5.585 \text{ ft}^2} = 216.89 \frac{\text{ft}^2}{\text{sec}}$$

$$Re = \frac{GD}{\mu} = \frac{38.35 \text{ lb ft}^2}{\text{sec } 2.14 \times 10^5 \; 16} \quad \frac{32 \text{ ft}}{12 \times 5.585 \text{ ft}^2}$$

$Re = 8.56 \times 10^{5}$

$$h = K \frac{V^2}{2g}$$

Assume worst duct bents 20 $f_t$ (1 bend) from Crane

Velocity Head

$$.03613 \frac{(216.89)^2 \mathrm{ft}^2}{2 \times 32.2} = 26.39 \frac{\mathrm{lb}}{\mathrm{ft}^2} = 0.1832 \frac{\mathrm{lb}}{\mathrm{in}^2}$$

$= .4228$ ft of $H_2O$ 5.073 in. of $H_2O$

$K = \left( f \frac{\ell}{d} \right) = f\ (30)\quad f_T 2 \quad 0.015$ Crane

$K_p = 0.015 \left( \frac{20}{32/R} \right) = 0.015\ (7.5) = 0.11$

$K_B = 2.0 \times 0.015 = .30$

$\Delta P = (1.30 + 0.11) = 1.41\ V_{head}$

$h_L = 2.08$ assume 50% margin

3.12 in. of $H_2O$

Assume combustor $\Delta P = 10$ in. of $H_2O$

Heat Exchanger $\Delta P = 6$ in. of $H_2O$

Turbine Exhaust Duct $\Delta P = \frac{3.1}{19.1}$

Base Output $\mathrm{KW}/\delta = 2060$

$\mathrm{KW} = 2060 \times .896 = 1845.76$ KW

Exhaust Loss $6.0\ \mathrm{KW}/_{n} = 6.0 \times 19.1 = 114.6$ KW

Net Output $1845.76 - 114.6 = 1731.2$ KW

# HEAT EXCHANGER

Starting at the back calculating pressure drops and temperatures.

Assume the $C_p$ for the gas the same as air.

$$T_{HX} = \left(1625 \text{ X} \cdot 2785 - \frac{34.5 \quad 213 \text{x} 10^6}{41.8 \text{ X } 3600}\right) 1.256$$

$$T_{HXO} = 223.16/.256 = 871.7$$

$$\Delta T_{log} = \frac{\Delta T_{in} - \Delta T_{out}}{\ln\left(\frac{\Delta T_{in}}{\Delta T_{out}}\right)}$$

$$\Delta T_{in} = 1625 - 1450 = 175°\text{F}$$

$$\Delta T_{out} = 871 - 597 = 274.79$$

$$\Delta T = \frac{175 - 274.7}{\ln\left(\frac{175}{274.7}\right)} = 221.18 \text{ F}°$$

$$Q = UA\Delta T \quad \rightarrow \quad UA = \frac{34.52 \text{ X } 10^6}{221.18}$$

$$UA = 156{,}070$$

## Air Side Pressure Drop

$$\Delta P = \Delta Pref \left(\frac{Pref}{P}\right) = 5.0 \left(\frac{134}{119.85}\right) = 5.59$$

The design $\frac{\Delta P}{P}$ for turbine 5.5% or $\Delta P = 6.59$ psi.

The heat exchanger $\Delta P$ is below design.

# GAS TURBINE

## Cold Day Condition

$T$ = 28°F = 488°R

$P$ = 13.17 psia

$\delta$ = 0.896

Pressure Ratio 9.46

$P_{c\ ot}$ = 9.46 X 13.17 = 124.59 psia

$T_{co}$ = 551°F

Mass Flow = 39.9 lb/sec

Heat Duty

$Q$ = 39.9 X 3600 (1450 X .275 - 551.X.25)

$Q = 37.45 \times 10^{6}$ BTU/hr

Turbine Exhaust Temp.

Tex = 692°F

Heat Exchanger at 28°F ambient condition.

$$Q = 39.9 \frac{\text{lb}}{\text{sec}} (1450 \times .275 - 551 \times .25)$$

$$Q = 37.49 \times 10^6$$

Ratio = up the combuster flow

43.49 lb/sec

$$T_{out} = \left(1625 \times .2785 - \frac{37.45 \times 10^6}{43.49 \times 3600}\right) \Big/ .256$$

$$T_{out} = 832°F$$

$$\Delta T_{log} = \frac{(1625 - 1450) - (832 - 551)}{\ln\left(\frac{1625 - 1456}{832 - 551}\right)} = 223.8$$

$$UA = \frac{37.49 \times 10^6}{223.8} \cong 167{,}516$$

Reduce Q by 4%

$$\text{Assume } Q = 36.00 \times 10^6$$

$$T_T = \left(\frac{36.00 \times 10^6}{39.9 \times 3600} + 551 \times .25\right) \Big/ .270 = 1438°F$$

$$T_{out} = \left(1625 \times .2785 - \frac{34.00 \times 10^6}{43.49 \times 9600}\right) \Big/ .258 = .912°F$$

$$\Delta T = \frac{(1625 - 1438) - (912 - 551)}{\ln\left(\frac{1625 - 1478}{912 - 551}\right)} = 264.$$

$$UA = \frac{36.00 \times 10^6}{264} = 136363$$

It appears the design area is too small to made rated temp. at a low ambient temp.

$T = 1444.°F$

# COLD CONDITIONS PRESSURE DROPS

Flow ratios

Turbine $= \frac{39.9}{38.35} = 1.0404 = FRT$

Heat Exhanger $= \frac{43.49}{41.8} = 1.0404 = FRH$

$FRT^2 = 1.082$

$FRH^2 = 1.082$

Ration the pressure by the flow squared since other conditions are the same.

$\Delta P_{HX} = 6 \times 1.082 = 6.5''$

$\Delta P_{com} = 10 \times 1.082 = 10.82$

$\Delta P_{duct} = 3.1 \times 1.082 = \underline{3.35}$

$20.67''\ H_2O$

Power Generation

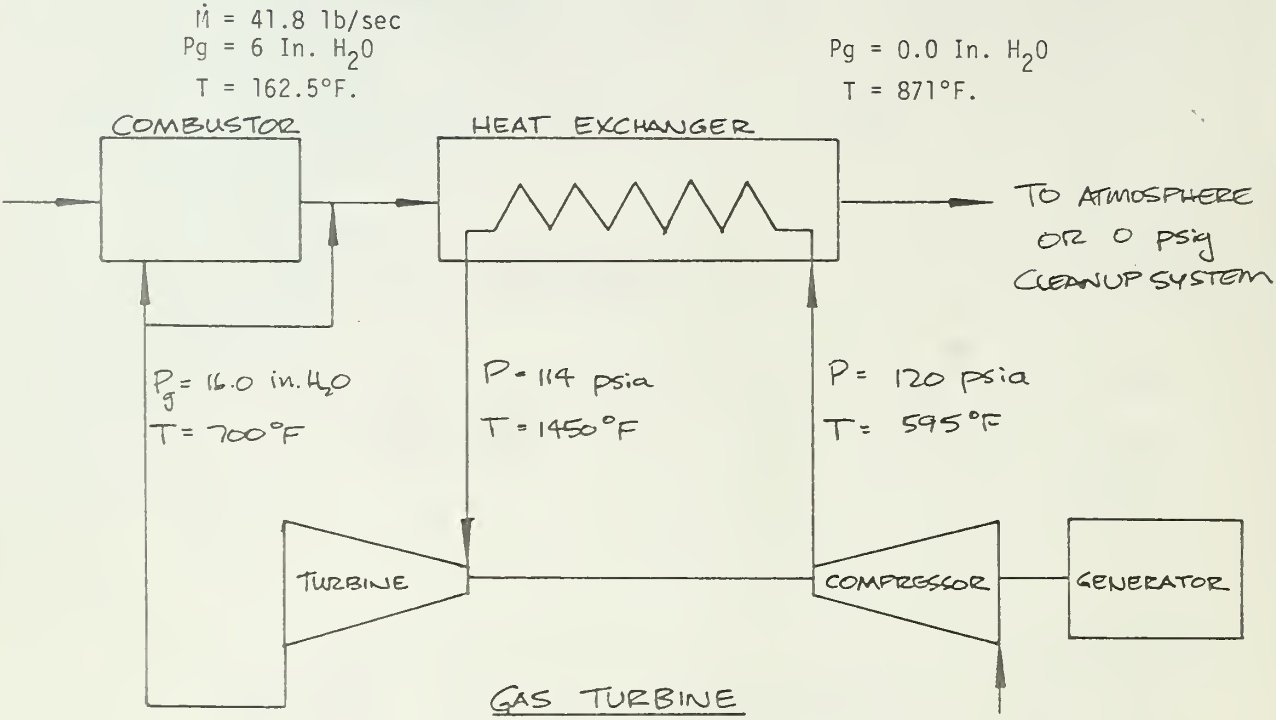
Base Output KW/g = 2385 KW

KW/ = 2385 X .896 = 2136.96

Exhaust Loss 6.25KW/In.$H_2O$ = 6.25 X 20.67 = 129.19

Net Output 2136.96 - 129.19 = 2007.77 KW

## CONDITIONS AT 59°F. AMBIENT



GAS TURBINE

Pg = 19.1 In. $H_2O$
T = 700°F.

| | |
|---|---|
| Gross Output | 1845.8 KW |
| Exhaust Loss | 114.6 |
| Net Output | 1731.2 KW |
| Heat Rate | |

$\dot{M}$ = 38.35 lb/sec
P = 13.17 psig
T = 59°F.

No Inlet Losses

Operating at 3000 Ft. or a pressure of 13.17 psig

Heat Exchanger has design basis as follows:

$$\Delta T_{\log} = 221.\text{°F.}$$

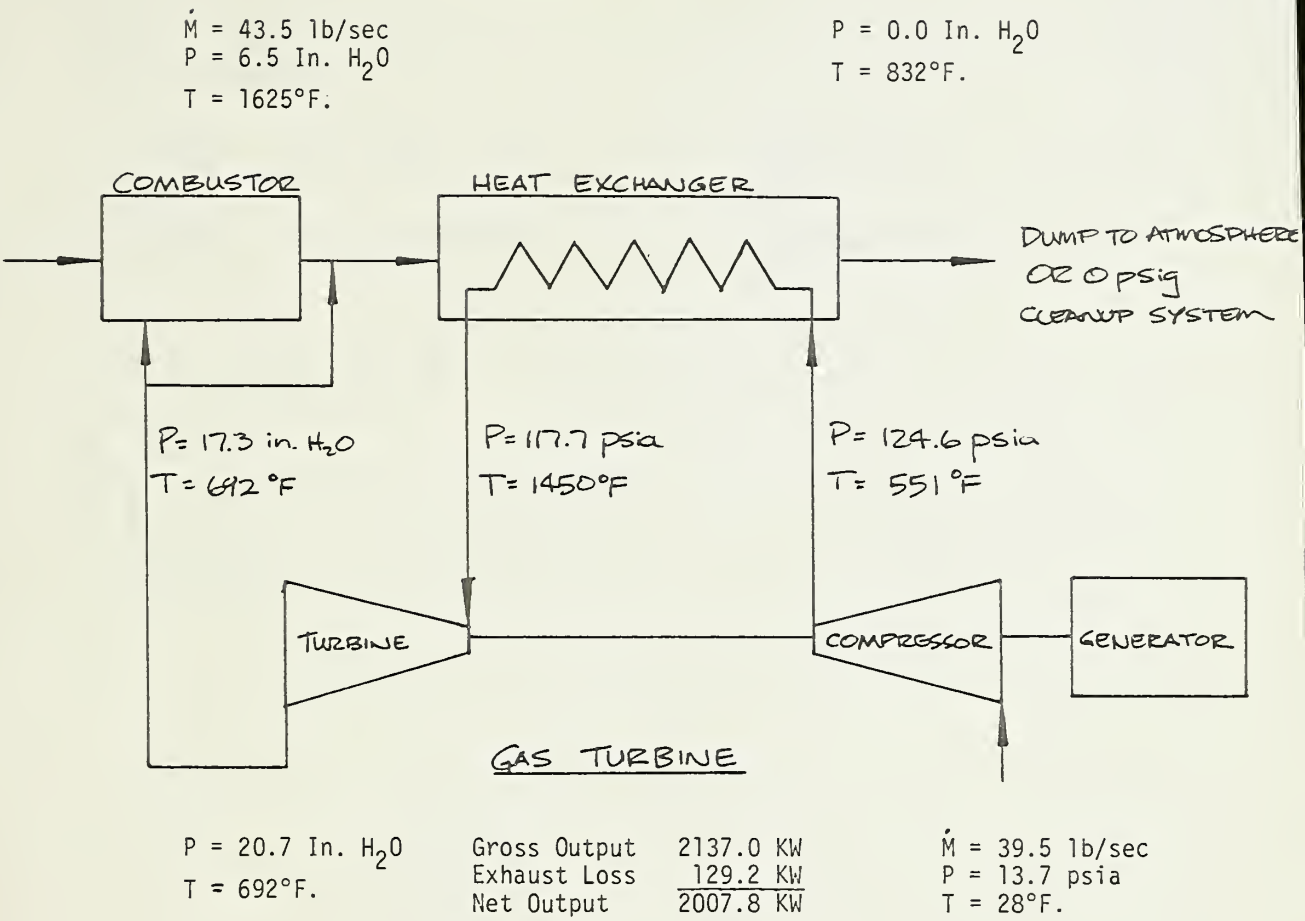
$$UA = 156{,}000 \text{ BTU/Hr.°F.}$$

$\delta = P/14.7 = 0.896$

All gases are assumed ideal gases

No Heat Losses

CONDITION AT 28°F. AMBIENT



No Inlet Losses

Operating at 3000 Ft. or a pressure of 13.17 psia

Heat Exchanger has design basis as follows:

$\Delta T_{\log} = 221.°F.$

$UA = 156,000$ BTU/Hr.°F.

$\delta = P/14.7 = 0.896$

All gases are assumed ideal gases

No Heat Losses

Heat Rate calculation based upon the additional heat requried to raise the gas temperature above the dryer inlet.

$$Q = 41.8 \times 3600 \, (1625 \times .2785 - 871 \times .258)$$

$$Q = 34.29 \times 10^{6} \text{ BTU/hr}$$

$$\text{Heat Rate} = \frac{34.29 \times 10^{6} \text{ BTU}}{1731.2 \text{ KW} \times \text{hr}}$$

$$\text{Heat Rate} = 19805. \frac{\text{BTU}}{\text{KW} \times \text{hr}}$$

Effects of Turbine inlet temperature.

1450°F @ 2060 KW

1370°F @ 1800 KW

$$\frac{2\ \text{Power}}{2\ T_T} = \frac{2060 - 1800}{1450 - 1370} = \frac{200}{40} = 3.25$$

$$\frac{2\ \text{Power}}{2\ T_T} = 3.25\ \text{KW}/^\circ\text{F} \longleftarrow$$

Assume a Turbine inlet temperature sensor error of $\pm$ 2%

$\pm$ 29°F → $\pm$ 94.25 KW

Effects of Turbine Back Pressure @ 59°F

$$\frac{2\ \text{Power}}{2\ \text{BP}_{\text{In.H}_{20}}} = 6.0\ \frac{\text{KW}}{\text{In.H}_2\text{0}} \longleftarrow$$

# APPENDIX C:

# RESUMES OF AUTHORS AND JAYCOR CAPABILITIES

MR. JAMES R. CARLSON

University of Utah
B.S. (1967); M.S. (1970), Mechanical Engineering
Registered Professional Engineer (Mechanical), State of California

Mr. Carlson has more than ten years experience in a broad range of engineering problems. This experience includes Project Management of engineering design for combined-cycle steam plants and various energy conservation studies. In addition, Mr. Carlson has made substantial contributions to the High-Temperature Gas-Cooled Reactor (HTGR) design effort.

Mr. Carlson joined JAYCOR in June of 1977 and has been the Principal Investigator on several projects involved in the development and utilization of power performance models, as well as performing power plant availability studies. Currently Mr. Carlson is Principal Investigator on an 18-month effort directed at identification of root causes of power plant outages attributed to boiler controls. Other major projects were the independent verification of the Fort St. Vrain (FSV) Transient Analysis Program (TAP), development of a non-reheat steady-state performance code for the HTGR and GCFR steam cycle, and consulting service to the FSV Project to improve the existing steady-state and transient performance models. In addition, Mr. Carlson is the Principal Investigator on a project to develop a steady-state performance model for a 100 MW(e) Line Focus Solar-Central Power System.

Prior to joining JAYCOR, Mr. Carlson was with the Hugh Carter Engineering Corporation in La Jolla, California, as Industrial Section Manager from May 1976 to June 1977. During this period, he was the Principal Investigator on several energy conservation and utilization studies, and Project Manager on the engineering design of a 300,000 lb/hr, 20 MW(e) combined electric-process steam co-generation plant.

During his tenure at General Atomic Company from 1969 to 1976, he worked in the steam generator development program and in the area of total system performance analysis. While in the steam generator program, Mr. Carlson was involved in problems concerned with operating performance, thermal sizing and boiling stability analysis, as well as developing methods of determining design margins and optimum configuration.

Mr. Carlson transferred to the Systems Analysis Branch in late 1972 where he was involved in developing more complete system performance models and used these models for developing total system and component design margins. He made model improvements to the computer codes SCAP and TAP, as well as directed the development of a multi-loop HTGR performance computer code. In addition to computer code development, Mr. Carlson contributed to the development of statistical methods for determining system design margins and predicting the probability of successful plant operation. He was involved in the system optimization studies during HTGR Alternate Cycle and SCE (4,000 MW(e)) Task Forces.

TERRY L. GREENLEE

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University of California at Los Angeles
B.S. (Engineering), 1967; M.S. (Control Theory), 1970; Ph.D. (Systems Science), 1973
Registered Professional Engineer, State of California

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Dr. Greenlee joined JAYCOR in 1979 as Manager of Systems Engineering in the Energy Division. He reports directly to the Vice President of the Energy Division and is responsible for management of all systems engineering efforts in the division.

Dr. Greenlee joined Hughes Aircraft Company in 1967, where he was a Hughes Masters Fellow and a Hughes Staff Doctoral Fellow. He worked in an analytical capacity on a variety of projects in the Space Systems and Missile Systems divisions, and was significantly concerned with application of modern estimation and control theory concepts to missile guidance problems.

In 1973 Dr. Greenlee joined General Atomic Company as Assistant Section Leader for the Control and Dynamics Branch. He directed and performed dynamic system analysis and control system synthesis for the high-temperature gas-cooled reactor. He also proposed and directed research and development work in the area of dynamic systems analysis.

During 1975, Dr. Greenlee served as a consultant and co-investigator to the Applied Systems Corporation on an ERDA/NRC study to examine the applications of estimation theory tok the nuclear safeguards problem. He joined the Electronics Division of General Dynamics Corporation later in the year as the principal engineer and director of data analysis planning for the Air Force NAVSTAR-Global Positioning System. He planned and developed the data analysis approach to be used in determining the accuracy of GPS position and velocity estimates.

In 1976 he became a principal engineer at Orincon Corporation and was involved in problems requiring application of operations research theory, information theory (including estimation and stochastic processes), and control theory. He maintained a strong involvement in a major program at the Naval Ocean Systems Center which required application of stochastic processes and estimation theory. He also directed Orincon's energy development program.

In 1978 Dr. Greenlee joined in the founding of ESSCOR, where he served as vice president, chief financial officer, and chairman of the board. He was a principal investigator on a number of contracts with Solar Turbines International which dealt with advanced applications of gas turbines.

Dr. Greenlee is a member of IEEE and a reviewer for the IEEE Transactions on Automatic Control. He is affiliated with the University of California at San Diego, where he has taught graduate courses in control theory, optimization theory, noise and random processes, estimation theory, network theory, and statistics.

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# JAYCOR QUALIFICATIONS

JAYCOR is a California corporation, founded in early 1975. In its fifth year of operation, JAYCOR sales exceeded $13 million, and current revenues are in excess of $1.3 million per month. As an indication of both its performance and cost control, JAYCOR has successfully completed its contracts on time and within cost. JAYCOR's staff includes over 200 professionals, including Ph.D. engineers, physicists, and related displines.

JAYCOR's technical staff is large and sufficiently diverse to carry out the needs of this contract for technical integration, engineering analysis, economic analysis, and administration and accounting. As of January 30, 1980, the rapidly growing JAYCOR staff included:

20 military analysts
4 chemical engineers
3 civil engineers
6 electrical engineers
4 mechanical engineers
1 mining engineer
2 structural engineers
25 administrative
150 physicists
4 chemists
9 fluid dynamicists
1 hydrologist
16 oceanographers
15 computer programmers
20 clerical
8 lab technicians

Some typical contract efforts in the last few years that are relevant to the present proposal are:

Mixing, pyrolysis, and agglomeration in coal conversion reactors - Department of Energy

Environmental studies program - Bureau of Land Management

Hites and Gites information enhancement and transfer system - Department of the Navy

Stimulation techniques for gas production from Devonian shales - Morgantown Energy Technology Center

Extraction of methanes from geopressured brines - IGT/GRI

Model of Bi-Gas Reactor - Phillips Petroleum

Mathematical modeling of steam generators for performance enhancement - EPRI

JAYCOR has experience in fossil energy research from concept feasibility assessment to pilot plant development. Current experience and contributions unique to JAYCOR include data acquisition and analytical systems for methanaton and gasification PDUs; simulation of mixing, pyrolysis, and agglomeration in coal conversion reactors; controller design and performance prediction for atmospheric fluidized-bed combustion steam generators; analyses of surface oil shale retorting; simulation of Devonian gas shales; development of static and dynamic power plant and thermofluid system performance models; performance improvement programs for large fossil-fuel power plant. Project examples are given in Table D-1.

Table D-1

|  | Project Title | Agency | Key JAYCOR Staff | Description of Work |
|---|---|---|---|---|
| 1. | Development of a 3-D Computer Model of the BI-GAS Gasifier | Phillips Co. (subcontract) | Dr. M. Scharff | Project to develop a 3-D, 2-phase, time-dependent model of stages 1 and 2, and the slag quench region of the BI-GAS gasifier, with emphasis on the fluid dynamics of the jet-driven flow patterns, effects of these on the product mix, particle paths, and slagging behavior of the system. |
| 2. | Mixing, Pyrolysis, and Agglomeration | DoE | Dr. M. Scharff | Project to develop and apply a computer model describing details of the flow of coal feed streams mixing with beds or streams of char and other solids. Includes detailed chemistry of agglomeration of caking coals. |
| 3. | Analysis of Data from LETC 10-ton Oil Shale Retort | DoE | Dr. M. Scharff | Project to provide data validation and analysis of 12 experiments at LETC's 10-ton oil shale retort, development of correlations. |
| 4. | Thermodynamics of Multiphase, Multispecies Systems | DoE | Dr. M. Scharff<br>Dr. H. Levine | Project to develop new user-oriented, high-speed computer program for solving multiphase, multispecies component chemical equilibria from LLL. |
| 5. | Analysis and Correlation of DoE Data | DoE | D. Laird | Analyze and correlate DoE-furnished data on retorting research and development at Anvil Points Facility. |
| 6. | Technical Support to the Eastern Gas Shales Project | ERDA | Dr. M. Scharff | Project to provide support for Eastern Gas Shales Project, managed by METC. Focus is on stimulation of gas from eastern gas shales, with emphasis on methods of employing chemical explosives. |
| 7. | BCR Coal Gasification Research Program | Industry/DoE | Mr. R. Young | Program encompasses the full range of engineering/environmental technologies implicit in development of a pilot-scale plant. |

|  | Project Title | Agency | Key JAYCOR Staff | Description of Work |
|---|---|---|---|---|
| 8. | Project to Provide an Experimental Plan for METC 6x6' Fluidized-Bed Combustor | ERDA | Dr. M. Scharff | Project to develop an experimental plan for the METC 6 x 6' fluidized-bed cold test model for research in atmospheric fluidized-bed combustion. Upon completion, the unit will be available for a variety of experiments directed toward achieving increased versatility, improved performance, and lower costs of fluidized-bed combusts, the purpose being to provide a plan for tests of some of these ideas, specifically partial slumping, alternative tube configurations, and enhanced dispersion of solids. |
| 9. | Computer Model of Fluidized Bed and Entrained Flow Coal Gasification Reactors | ERDA | Dr. M. Scharff | Early models (1975) of these processes were developed under this contract, beginning with $CO_2$ acceptor process. |
| 10. | A. Development of Computer Simulation Models for Fluidized-Bed Coal Gasification | ERDA | Dr. H. Levine | Program required development of the chemistry models for inputs to system codes. |
|  | B. Coal Devolatilization and Hydrogasification, Char Combustion, and Gas-Phase Reactions | Industry/DoE | Dr. H. Levine | Chemical processes involved were analyzed and a computer model formulated. |
| 11. | Modeling of Combustion of Pulverized Coal | EPRI/ERDA | Dr. J. Wormeck | Program concerned the modeling of combustion of pulverized coal by solving complete hydrodynamic equations simultaneously with gas-phase reaction mechanism, two-phase flow of particles considering finite-rate burning and radiation, and development of procedures to calculate transport coefficients efficiently. |

JAYCOR qualifications include extensive experience in process control and instrumentation engineering. Experience of JAYCOR personnel in control covers the full range of control systems from simple single-input/single-output analog controllers to multivariable, high-speed, real-time digital microprocessor- and computer-based systems. We have participated in conceptual design, engineering, and testing of control instrumentation. JAYCOR has a fully instrumented laboratory at its Del Mar facility dedicated to these functions. Experience of JAYCOR personnel in instrumentation and data acquisition includes specifying, acquiring, and operating minicomputer-controlled data acquisition systems in several coal conversion process development units. JAYCOR has also provided a variety of safety tools to the energy industry such as annunciators for alarm indications and state-of-the-art nuclear reactor safety codes used in cooling system design by EPRI, Westinghouse, General Electric, and General Atomic. Examples of projects successfully completed in this area appear in Table D-2.

Our staff has a recognized background in energy modeling and analysis, applied to in-situ oil shale retorting, coal gasification, fluidized-bed combustion, fusion, high-energy laser systems, thermofluid systems, hydrodynamics, relativistic charged-particle beam transport, ocean and estuarian plumes, sediment transport phenomena, and simulation of nuclear and fossil power systems operations. In addition, our broad interdisciplinary technical and management background provides us with the research planning capability to address energy research and resource allocation issues at all levels of program management. Examples are given in Table D-3.

Resumes of key personnel expected to be associated with the proposed program are presented on the following pages.

Table D-2

| | Project Title | Agency | Key JAYCOR Staff | Description of Work |
|---|---|---|---|---|
| 1. | Control Simulation Development | General Atomic Company | Dr. M. Ringham | Development of an overall open-loop, dynamic simulation of gas-cooled breeder reactor for control analysis purposes. |
| 2. | Optimization of High-Temperature Gas-Cooled Reactor Steam Cycle | General Atomic Company | Mr. J. Carlson | Implementation of three alternative steam cycles in a steam cycle analysis program. Sensitivity analyses were done to assist G.A. establish costs of alternative cycles. |
| 3. | Transient Analysis Computer Code Verification | General Atomic Company | Mr. J. Carlson | Engineering verification of transient analysis program (TAP) of the HTGR. |
| 4. | Test Planning, Collection and Analysis of Pressure Data from Army Weapon Systems | Walter Reed Army Inst. of Research | Mr. L. Roelofs | Independent analysis of pressure and frequency data from shock tube experiment. JAYCOR assisted in identifying potentially hazardous weapons systems, determining essential data elements, test planning, collection and reduction of data, data analysis and review. |
| 5. | Independent Review of Fort St. Vrain Nuclear Power Plant | General Atomic Company | Dr. M. Ringham | Technical review and independent verificaton of reactor safety code RECA for the Fort St. Vrain nuclear power plant. |
| 6. | Radiation-Hardening of Satellite Frequency Standards | DNA | Dr. T. Flanagan | Continuing studies and tasks relating to radiation-hardening of frequency standards for GPS applications. |
| 7. | Air Quality Criteria for Lead | EPA | Dr. M. Dowe | Support EPA in preparation of a comprehensive document assessing the environmental impacts of lead, with particular focus on air quality. |
| 8. | Digital Process Controls | METC | Dr. D. Berkowitz | Consultant on design/specification of direct digital control system with electronic-analog backup and distributed controller for atmospheric fluidized-bed combustion component test and integration unit. |

|  | Project Title | Agency | Key JAYCOR Staff | Description of Work |
|---|---|---|---|---|
| 9. | Two-Phase Flow Analysis Related to Reactor Safety | EPRI | Dr. J. Stuhmiller | Definition of major issues associated with development and application of mathematical models to nuclear reactor fluid flow problems. |
| 10. | Development of a Study of Pumps | INEL | Dr. P. Nakayama | Develop a computer model to simulate the performance of jet pumps in nuclear jet reactors under transient conditions. |
| 11. | BWO Plant-Unique Analysis | General Electric | Dr. P. Nakayama | Fluid-dynamically induced loads in Mark I BWR pressure suppression systems for plant-unique analysis; work complied with 10CFR-50 requirements because it had licensing impact. |
| 12. | Steam Chugging Analysis | EPRI | Dr. J. Stuhmiller | Develop a model of rapid steam condensation in BWR steam suppression pools. |
| 13. | BWR Cool-S Well Dynamics | EPRI | Dr. J. Stuhmiller | Develop and implement new models of multidimensonal 2-phase flow for study of safety issues in nuclear reactors. |
| 14. | BARR-II Code Development | Westinghouse | Dr. P. Nakayama | Develop time-dependent, thermohydraulic code for liauid sodium reactors at Clinch River to examine thermal transients under SCRAM conditions. |
| 15. | Process Development Unit, Real-Time Data Acquisition System | DoE | Dr. D. Berkowitz | Installation of minicomputer-based data acquisition system at atmospheric fluidized-bed combustion process development unit. |
| 16. | Model Generating Unit 4 at Mystic Station | Boston Edison Company | Dr. D. Berkowitz | Design and installation of modified fuel controller to improve load-following capability and stability of operation at intermediate level. |

|  | Project Title | Agency | Key JAYCOR Staff | Description of Work |
|---|---|---|---|---|
| 17. | Analog Process Controls (Electronic) | METC | Dr. D. Berkowitz | Design of primary electronic-analog control algorithms for proposed atmospheric fluidized-bed combustion component test and integration unit. |
| 18. | Mathematical Modeling of Generating Unit 4 at Mystic Station | Boston Edison Company | Dr. D. Berkowitz | Develop mathematical model of plant and pneumatic control system to simulate performance of generating unit. |
| 19. | Development of VARR-II Computer Code | Westinghouse | Dr. J. Stuhmiller | Develop a 2-dimensional turbulent computer code for reactor safety and design studies. |

Table D-3

|  | Project Title | Agency | Key JAYCOR Staff | Description of Work |
|---|---|---|---|---|
| 1. | Transient Analysis Computer Code Verification | General Atomic Company | Mr. J. Carlson | Engineering verification of transient analysis program (TAP) of the high-temperature gas reactor. |
| 2. | Support Laramie Energy Research Center | DoE | Mr. D. Laird | Data reduction, analysis, correlation of retort experiments designed to simulate in-situ processing of oil shale. Review procedures, identify faulty experiments, determine optimum operating point. |
| 3. | RDF Process Evaluaton | SCURPO | Dr. M. Dowe | Concept formulation and analysis of refuse-derived fuels processing plant for San Diego. |
| 4. | High-Speed Computer Program | Lawrence Livermore Laboratory | Dr. H. Levine | Development of multicomponent, multiphase chemical thermodynamic equilibria using advanced mathematical techniques. |
| 5. | Numerical Investigation for OTEC | ONR/DOE | Dr. H. Hurlbut | Development of two-layer numerical model for OTEC sites in Gulf of Mexico. |
| 6. | Development of Model to Study Jet Pumps | IMEL | Dr. P. Nakayama | Develop a computer code to simulate performance of jet pumps in nuclear reactors under transient conditions. |
| 7. | Steam Chugging Analysis | EPRI | Dr. J. Stuhmiller | Develop model of rapid steam condensation in BWR steam suppression pools. |
| 8. | BARR-II Code Development | Westinghouse | Dr. P. Nakayama | Develop time-dependent thermohydrodynamic code for liquid sodium reactors at Clinch River. |
| 9. | Navy Survivable CCC Systems | Navy | Mr. J. Don Carlos | Planning activities: exploratory development through production, ELF through optical frequencies, system analysis through hardware development, microminiaturized information processing system through multimegawatt transmitting systems. |

| Project Title | Agency | Key JAYCOR Staff | Description of Work |
|---|---|---|---|
| 10. Circuit Logic Design | Hains Corp. | Dr. S. Adams | Develop model for design, design optimizaton, and process management for various electronic systems involving adaptive arrays and data communication systems. |
| 11. High-Energy Laser | Navy | Mr. L. Roelofs | Analysis of long-range program organization and planning, modeling, and data validation. |
| 12. Multi-Source Data Modeling | CIA | Mr. C. Skiscim | Develop advanced data management systems for processing, compiling, sorting, and collating multi-source, multi-valued data. |
| 13. Multi-Attribute Utility Functions | ARPA | Mr. C. Skiscim | Develop novel methodology for estimating multi-attribute utility functions and their use in comparative evaluation of technological innovations. |
| 14. Water Quality Planning/Management | State of Virginia | Dr. J. Soukup | Planning the management of water quality programs for state agencies. |

# APPENDIX C

# NOTICE OF INTENT

# TO SELL FIBEROUS WASTE

Dear Sir:

This will convey our intention to sell to ___________ the fiberous wood waste generated at our ___________ plant.

The estimated quantity of fiberous waste available for purchase is estimated at _______ units per day. 200 cubic feet shall constitute one volumetric unit. We reserve the right to retain fiberous waste for our own use.

The estimated price of the fiberous waste, F.O.B. our own plant, will be $______ per unit. Semi-annual adjustments of the price shall be mutually agreed upon.

We further understand that prior to the actual sale of the fiberous waste a contractual agreement will be entered into with ___________.

Company or Corporation ___________________________________________

Manager or Officer ___________________________________________

Date ___________________________________________

# LETTER OF INTENT

IN THE SERIOUS INTEREST OF COMMITTING CAPITAL, RAW MATERIAL, AND ENGINEERING FOR THE PURPOSE OF ACTUAL CONSTRUCTION OF A SOLID FUEL REFINING PLANT, THE FOLLOWING COMMITMENT OF MUTUAL DEVELOPMENT IS OBSERVED BY BOTH PRINCIPAL PARTIES:

1. EAGLE ENERGY SYSTEMS, INC. COMMITS ITS INTENTION OF SUPPLYING
   (company) ______________________________
   WITH APPROXIMATELY __________ TONS PER YEAR MINIMUM TO __________ TONS PER YEAR MAXIMUM OF SOLID FUEL ON A RELIABLE LONG TERM BASIS.

2. (company) ______________________________
   COMMITS ITS INTENTION OF PURCHASING __________ TONS PER YEAR MINIMUM TO __________ TONS PER YEAR MAXIMUM ON A CONSISTANT, LONG-TERM BASIS.

3. THE BEGINNING OF DELIVER WOULD PREFERABLY OCCUR ON THE FOLLOWING DATE: ______________________________

AS THE ACTUAL PRODUCTION DATE APPROACHES, EAGLE ENERGY SYSTEMS, INC. AND SAID COMPANY DECLARE THEIR MUTUAL INTENT TO ENTER INTO A FIRM FUEL CONTRACT RELATIONSHIP.

______________________________
(OFFICER SIGNATURE)

______________________________
(FIRM NAME)

______________________________
(ADDRESS)

______________________________

______________________________
(DATE)

______________________________
(OFFICER SIGNATURE)

EAGLE ENERGY SYSTEMS, INC.

North 1332 Post Street
Spokane, Washington 99201

P.O. Box 3452
Missoula, Montana 59806

# APPENDIX D

# APPENDIX C SAMPLE LEGAL CONTRACTS

## WASTE WOOD FUEL SUPPLY AGREEMENT

THIS AGREEMENT is made this _____ day of __________, 19__, between EAGLE ENERGY SYSTEMS, INCORPORATED, a Montana Corporation, ("Eagle") and ________________________, ("Seller").

RECITALS:

a. Eagle is to engage in the effort of generating electricity from waste wood, which effort serves the public interests of creating additional energy and disposing of waste wood within the capabilities of Eagle's generating facilities.

b. Eagle requires an assured adequate supply of waste wood to fuel its generating facilities.

c. Seller desires to sell its waste wood and to increase the market for waste woods through the establishment of Eagle as a continuing waste wood purchaser.

d. Both parties, individually and without relying on the representations of the other, recognize the uncertainties attendant Eagle's pioneering effort and accept the following as reasonable and mutually beneficial: all terms of this Agreement; the organization and structure of Eagle; and the size and limited capacity of Eagle's generating facilities.

The parties mutually agree as follows:

1. WASTE WOOD: In accordance with the terms and conditions of this Agreement, and except as otherwise limited by this Agreement, Seller shall sell to Eagle and Eagle shall have the right to purchase from Seller all waste wood produced by Seller and loaded into Eagle's truck at Seller's loading facilities located at various sites. ____________

______________________________________________________________

2. TERM: This Agreement begins on the date of execution and continues for an initial term of ten (10) years from the date of the first delivery of waste wood under this Agreement. Deliveries shall commence when Eagle's fuel handling and storage facilities are ready to receive wood waste from the Seller, which is now projected to be on or about

________________.

3. BASE PURCHASE PRICE: Eagle shall pay to Seller the base purchase price of __________ per 2,000 pound ton received for waste wood sold under this Agreement and loaded into Eagle designated vehicle(s) at Seller's facilities.

4. PAYMENT: Eagle shall pay the base purchase price to Seller by the 25th day of the following month for wood waste deliveries accepted during the previous month. Payment may be mailed to Seller's address specified in Section ____ below, and if so mailed, will be deemed paid when posted.

5. QUANTITY DELIVERED: Seller has agreed to guarantee the supply of a minimum of __________ tons of wood waste to Eagle per year for ____ years.

6. SPECIFICATIONS: Waste wood quantities and types are identified as to product lines found in Attachment A. Maximum moisture content fifty percent on a wet basis, and reasonably free of foreign materials such as rocks and metal. Typical wastes would include bark and hog fuel, and Seller may include other items such as chips, sawdust and shavings at its own option. Seller shall use reasonable care to keep waste wood free from moisture, rocks, dirt, metal and other non-burnable materials. Ninety percent of wood waste by weight shall be two feet in size or smaller, with a maximum size of either a twenty-four inch diameter log two feet long or a twelve-inch diameter log eight feet long. Eagle will adjust the quantity delivered by Seller should there by a significant reduction or increase in fuel heat value or quality from normal waste wood purchased by Eagle. Waste wood deliveries loaded into a Eagle designated vehicle for transportation to Eagle's generating facilities

shall be capable of unloading, preparing, and handling by Eagle's facilities. Eagle will assist Seller in determining the specifications and acceptability of unusual or unprepared waste wood.

Log deck debris and yard waste are considered separate from the wood waste produced during the typical recovery efforts. Eagle will accept yard waste providing the parties agree on a mutually acceptable handling method. The price for yard waste will be determined on how nearly the prepared yard waste compares to the typical waste wood specification described above in both physical and heat content characteristics. The estimated annual quantities for yard waste is __________ tons per year.

7. MEASUREMENT: The unit of measurement for waste wood shall be the ton, which equals 2,000 pounds of wood waste as recovered and produced at a Seller's site. The measurement of tons shall be at Eagle weighing facilities or at a weighing station designed by Eagle. Eagle shall determine the weight of each load of waste wood delivered by weighing the loaded vehicle and deducting the car weight, or by any other mutually satisfactory method. In the event of the breakdown of Eagle's weighing or receiving facilities, Eagle may estimate load weights at Eagle's facilities or use the average of Seller's most recent loads. Seller may, at reasonable times, inspect Eagle's measurement procedures and records.

8. QUANTITY ADJUSTMENT: Should the quantity of waste wood accepted by Eagle vary significantly from the normal waste wood specified, a quantity adjustment shall be determined and imposed by Eagle in proportion to the deviation from the specifications. Quantity adjustments will be subject to approval by Eagle.

9. INSPECTION: Eagle may inspect any wood waste loads at Seller's facilities and/or at Eagle facilities. Inspection of any wood waste load by Eagle shall occur within forty-eight (48) hours after the load arrives at Eagle's facilities.

10. REJECTION: For any load determined by Eagle, in its sole discretion, to not meet the specifications of this Agreement, Eagle may either accept the load notwithstanding its failure to meet the specifications or reject the load by giving reasonable written or oral notice to Seller of such rejection. If Eagle fails to so notify Seller, wood waste received by Eagle shall be deemed to be accepted. Upon rejection, title to rejected wood waste immediately passes to Seller and shall be subject to Seller's disposition within twenty-four (24) hours. All freight and demurrage charges following notice of rejection of wood waste shall be paid by Seller.

11. SHIPMENT TERMS: Except as otherwise provided in this Agreement the shipment terms for this Agreement are FOB Seller's facilities Eagle designated vehicle. Eagle shall provide transportation for wood waste from Seller's facilities to Eagle's facilities unless otherwise specified. Seller shall provide access to Seller's facilities and loading for Eagle designated vehicle. Typcial open top chip vans will be used to transport waste wood. Risk of loss for each individual load passes from Seller to Eagle upon the completion of loading into the vehicle designated by Eagle for that load.

12. LOADING AND UNLOADING: Seller shall provide suitable on site storage and loading facilities to promptly load Eagle's designated vehicles to maximum capacity in accordance with the carrier's specifications. Seller shall not load stockpiled wood waste for shipment without prior written approval from Eagle.

Mutually acceptable unloading schedules will be coordinated between Eagle and Seller, provided that neither party use this to unreasonably delay unloading. Eagle shall provide suitable unloading facilities to accommodate designated vehicles. Eagle may designate alternate unloading destinations from time to time.

13. CURTAILMENT AND SUSPENSION: Eagle may from time to time curtail or suspend power production at its facilities for any reason. Eagle shall give Seller reasonable notice of any such curtailment or suspension. In the event of such notice, then for the duration of the curtailment or suspension, Eagle is relieved of its obligation under this Agreement to purchase waste wood from Seller. During a curtailment or suspension of power production at Eagle's facilities, the reduction in volume of waste wood shall be prorated to all suppliers who are then parties to waste wood fuel supply agreements with Eagle.

14. TERMINATION: At any time prior to ____________, Eagle may terminate this Agreement by giving written notice to Seller. At any time after ____________, Eagle may terminate this Agreement by giving twelve (12) months written notice to Seller.

At any time after ____________, Seller may terminate this Agreement by giving twelve (12) months written notice to Eagle if during any consecutive twelve-month period Eagle shall not have accepted fifty percent (50%) of qualifying waste wood quantities defined in Attachment A, except for quantity reductions caused by notice of curtailment of suspension.

15. DEFAULT: Should either party default in the performance of its obligations under this Agreement, including but not limited to the

obligation to deliver waste wood in accordance with the specifications set forth above in Section ___, then the non-defaulting party may terminate this Agreement by giving written notice to the defaulting party. In the event that either party should be adjudicated as bankrupt, in the case of either party's insolvency (in either the equity or balance sheet sense), or if a receiver should be appointed for either party, then the other party, without previous notice and withour liability, may immediately either suspend or terminate it obligations under this Agreement, provided that written notice of such suspension or termination is given to such party as soon as practical thereafter.

16. ASSIGNMENT: This Agreement shall inure to the benefit of and be binding upon the parties hereto, together with their respective heirs, successors, executors, and administrators, or assigns, but this Agreement shall not be assignable by either party without prior written consent of the other party.

17. FORCE MAJEURE: If, because of force majeure, any party shall be unable to carry out any of its obligations under this Agreement, then the obligations of such party shall be suspended to the extent made necessary by such force majeure. The affected party shall give notice to the other party as promptly as practicable of the nature and probable duration of such force Majeure. The term "force Majeure" shall mean acts of God, legislation or lawful regulations of any governing body, court orders, acts of a public enemy, riots, labor disputes, labor or material shortages, fires, explosions, floods, breakdowns or damage to plants, transmission lines, equipment or facilities, economic turndowns, interruptions in transportation or other causes of a similar nature which wholly or partially prevent

the delivery of the waste wood by Seller, the receiving or consuming of the waste wood by Eagle, or the construction, operation or maintenance of Eagle's generating facilities. Eagle and Seller shall use all reasonable means of preventing the occurrence of any of the foregoing. Any party rendered unable to fulfill any obligation by reason of force majeure shall exercise due diligence to remove such inability with all reasonable dispatch. This provision shall be in effect if Seller elects to guarantee a specific quantity of fuel during a specified term as indicated in Section ___ of this Agreement.

18. NOTICE: Any notice required to be given by one party to the other under this Agreement or by law shall be effectively given on the date of personal delivery, or if mailed, three (3) days after deposit in the United States mail, first class, postage prepaid, certified, or registered, and addressed as follows:

If to Eagle:
Eagle Energy Systems, Incorporated
1322 North Post Street
Spokane, Washington 99201

If to Seller:

______________________________
______________________________
______________________________

19. GOVERNING LAW: This Agreement shall be construed and interpreted in accordance with the laws of the State of ________.

The parties hereto executed this Agreement in duplicate on the day and year first above written.

| | |
|---|---|
| ______________________________ | EAGLE ENERGY SYSTEMS, INCORPORATED |
| By: ________________________ | By: ________________________ |
| Its: ________________________ | Its: ________________________ |

# TYPICAL INFORMATION NEEDED FOR A PLAN REVIEW

1. Dimensioned site plan locating the building on the property and showing distances to property lines, streets, roads alleys, and any other buildings on the site

2. Dimensioned floor plan showing walls, opening sizes, operating windows, door swings, door hardware, room or area uses, and exit signs.

3. Typical sections through the building showing footings, foundations, walls; floor, ceiling and roof materials, and details. (Roof trusses shall be in accordance with the design of a licensed engineer)

4. Provide roof and floor framing plans showing member sizes, spacing of members, and location of beams posts and footings.

5. Show all building insulation and how the building is heated and ventilated. Verify adequate combustion air for all fuel fired Units.

## BUILDING PERMIT FEES

From Page 36 of Uniform Building Code, 1979 edition.

| OTAL VALUATION* | FEE |
|---|---|
| 1.00 to $500 | $10.00 |
| 501 to $2,000 | $10.00 for the first $500 plus $1.50 for each additional $100 or fraction thereof, to and including $2,000. |
| ,001 to $25,000 | $32.50 for the first $2,000 plus $6.00 for each additional $1,000 or fraction thereof, to and including $25,000. |
| 5,001 to $50,000 | $170.50 for the first $25,000 plus $4.50 for each additional $1,000 or fraction thereof, to and including $50,000. |
| 0,001 to $100,000 | $283.00 for the first $50,000 plus $3.00 for each additional $1,000 or fraction thereof, to and including $100,000. |
| 00,000 and Up | $433.00 for the first $100,000 plus $2.50 for each additional $1,000 or fraction thereof. |

AN REVIEW FEES WILL BE CALCULATED AND BILLED TO THE PROPER PARTY.
FORE FINAL APPROVAL OF PLANS IS ISSUED, THE FEE MUST BE PAID.

e total construction valuation includes the value of all finish work,
nting, roofing, electrical, plumbing, heating, air conditioning,
vators, fire-extinguishing systems, and any other permanent work or
manent equipment.

hools that are issued building permits by local government will be
arged 65% of these fees.)

STATE OF MONTANA
BUILDING CODES DIVISION
CAPITOL STATION
HELENA, MONTANA 59601

# PLAN REVIEW APPLICATION

Plan Review Fee ____________ Plan Check No. ____________

General: ____________

Date Received: ____________ Date Approved: ____________

Job Address or Location: ____________

City: ____________ Construction Cost: ____________

Owner: ____________ Address: ____________

Designer: ____________ Address: ____________

Contractor: ____________ Address: ____________

Design Information:

Type of Work: ☐ New ☐ Addition ☐ Alteration ☐ Repair ☐ Move ☐ Demolition

Building Use: ____________

Occupancy Group: ____________ Type of Construction: ____________

No. of Stories: ____________ Height: ____________

Actual Area/Floor: ____________

Allowable Area/Floor: ____________

Basis for Area Increase: ____________

Occupant Load: ____________

Seismic Zone: ____________ Wind Pressure: ____________

Floor(s) Load(s): DL ____________
LL ____________

Roof(s) Load(s): DL ____________
LL ____________

Soil Bearing Capacity: ____________ Tested: ☐ YES ☐ NO

COMMENTS OR ASSUMPTIONS:

## PROVISIONAL PERMIT

When Properly Validated (In This Space)
This is your Provisional Permit

*PERMIT NO.* ____________

I hereby certify that I have read and examined this application and know the same to be true and correct. All provisions of laws and rules governing this type of work will be complied with whether specified herein or not, the granting of a provisional permit does not presume to give authority to violate or cancel the provisions of any other state or local law regulating construction or the performance of construction.

____________ *Signature of Applicant* ____________ *Date*

____________ *Signature of Approval* ____________ *Date*

Plumbing, Electrical, Mechanical and other permits may be required. Also, check local zoning requirements.

*DISTRIBUTION: Submit white and yellow copies to the Building Codes Division. Retain pink copy for your records.*

# AIR QUALITY PERMIT APPLICATION INSTRUCTIONS

Complete all items on the application form. In addition, the following information must be supplied:

1. Equipment Location Drawing. A drawing or sketch must be submitted to scale (suggested 1" = 100', measurement to nearest 5') showing at least the following:
   - a) the property involved, and outline and height of all buildings on it. Identify property lines plainly.
   - b) the location and identification of the proposed equipment on the property.
   - c) the location of the property with respect to streets and all adjacent properties. Identify adjacent property and buildings on it. Indicate North.
2. Equipment Description. State make, model, size and type for the entire unit and/or its major parts. Include such drawings as are necessary to show clearly the design and operation of the equipment and the means by which air contaminants are controlled. Included should be sizes, shapes and dimensions of the equipment and information which may affect the production, collection, conveyance or control of air contaminants. Include full details for fuel burners. Give type of fuel and quantity burned, BTU rating and % sulfur. Manufacturer's catalogs may be used if they provide sufficient information.
3. Description of Process. The application must be accompanied by a written description of all processes affected by the equipment. Supply all data regarding the process. Note all points or possible points of emissions, and types and quantities of contaminants emitted. If available, state volumes, particle sizes, concentration and nature of air contaminants. Describe control methods and efficiencies. Give the operating schedule (hrs/day. days/week). Detail type and total of materials being processed on the basis of pounds/hour or other unit of time on a process flow diagram. Estimate the amount of downtime.
4. Radioactive Material. Describe the use and processing of radioactive material.

If authority to construct is granted, deviations from the approved plan are not permissible without prior approval from the Air Quality Bureau.

Additional information may be required, and on request, certain requirements may be waived.

Further information or clarification concerning applications can be obtained by calling or writing the Montana State Department of Health and Environmental Sciences, Air Quality Bureau, Helena, Montana 59601. Phone: 406-449-3454.

Permit No.________________

AIR QUALITY PERMIT APPLICATION FOR SOURCES OF AIR POLLUTION
Montana State Department of Health and Environmental Sciences
Air Quality Bureau
Helena, Montana 59601 Phone: 406-449-3454

Applications are incomplete unless accompanied by copies of all plans specifications and drawings required. Details required for specific equipment are available on request. This application must be signed by a responsible member of the organization that is to operate the equipment for which application is made.

INCOMPLETE APPLICATIONS ARE NOT ACCEPTABLE.

1. Permit to be issued to (business license name of organization that is to operate the equipment):

Name________________________________________

☐ Corporation ☐ Partnership ☐ Individual ☐ Government

Address________________________________________

____________________________ Zip Code__________

2. Address at which equipment is to be located:____________________

________________________________________

3. General Nature of Business:____________________________

________________________________________

4. General Equipment Description:____________________________

________________________________________

________________________________________

5. Estimated Cost of Equipment of Alterations:

Basic Equipment $________________ Air Pollution Control Equipment $__________

6. Present Status of Equipment: Check and Complete Applicable Items.

| | Estimated Starting Date | Estimated Completion Date |
|---|---|---|
| ☐ New Installation | __________ | __________ |
| ☐ Alteration to Existing Installation | __________ | __________ |
| ☐ Transfer of owner, operator or lessee | __________ | __________ |
| ☐ Transfer of location | __________ | __________ |

(continued)

7. If this equipment had a previous permit, give:

Name________________________________ Most Recent Permit Number________________

8. Name, title and signature of responsible member of firm:

Name (Print or Type)____________________________________________

Title___________________________________________________________

Phone Number____________________________

Signature________________________________________ Date_________________________

Person to contact regarding this application:

Name______________________________________________ Phone______________________

# INSTRUCTIONS TO APPLICANTS

The notice below must be published no earlier than 10 days prior to the date your pplication will be submitted to the Department, and no later than 10 days following he date of submittal. The notice is to be published in the legal notice section of a newspaper of general circulation in the area affected. Questions regarding n appropriate newspaper should be addressed to the Bureau. Please submit a copy f the published notice to the Bureau with the application, if possible, or as soon thereafter as possible.

This notice is required by ARM Title 16, Chapter 8, Sub-chapter 11, ARM 16.8.1107.

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# PUBLIC NOTICE

Notice of Application for Air Quality Permit (Pursuant to Section 75-2-211, MCA, and ARM Title 16, Chapter 8, Sub-chapter 11, PERMIT, CONSTRUCTION AND OPERATION F AIR CONTAMINANT SOURCES,

______________________________________________________________

Name of Applicant) (has filed/ will file)

on or about ______________________ an application for an air quality
(date)

ermit from the Air Quality Bureau (Bureau) of the Environmental Sciences Division, Montana Department of Health and Environmental Sciences. Applicant seeks approval of its application for ______________________________________________
(brief description of construction modification, etc,

______________________________________________________________
project for which permit is being applied for)

The Bureau must determine whether or not the application is complete within 30 days of receipt of the application. Within 40 days of the receipt of a completed pplication, the Bureau will make a preliminary determination whether the permit should be issued, issued with conditions or denied. Any member of the public who wishes to receive notice of the Bureau's preliminary determination, and the location where a copy of the application and the Bureau's analysis of it can be reviewed, or to submit comments on the preliminary determination, must contact the Bureau at the Cogswell Building, Helena, Montana 59601 (phone (406) 449-3454).

Any comments on the preliminary determination by persons requesting and eceiving the above notification must be submitted to the Bureau within 15 days after the notification is mailed. The notification will also contain the date when the final decision on the application will be made by the Bureau, the name of the person from whom a copy of the final decision may be obtained, and the procedure or requesting a hearing of the decision before the Board of Health and Environmental Sciences.

# APPENDIX E

## AN OUTLINE

## THE WOOD RESIDUE UTILIZATION ACT OF 1980
PL 96-554 DECEMBER 19, 1980
(S-1996, HR 6755)
(Underlining added for highlighting)

SECTION 1: - To authorize a pilot program to encourage the efficient utilization of wood residues, and for other purposes.

SECTION 2: - The purpose of this Act is:

1. to develop, demonstrate and make available
   - a. information on feasible methods that have potential commercial application to:
     - (1) increase and improve utilization,
       - (a) in residential,
       - (b) commercial and,
       - (c) industrial or powerplant applications;

     of wood residues resulting from:
       - (1) timber harvesting and
       - (2) forest protection and management activities, occuring on public and private forest lands and
       - (3) the manufacture of forest products including wood pulp,

SECTION 3: - The Secretary of Agriculture is authorized to:

1. establish pilot projects and demonstrations to carry out the purposes of this Act.

The pilot projects and demonstrations established under this section

- (a) may be operated by the Secretary (force account) or,
- (b) may be carried out through contracts or agreements with owners of private forest lands or,
- (c) in conjunction with projects, contracts, or agreements entered into under any other authority which the Secretary may possess,

2. PROVIDED: That nothing contained in this Act shall abrogate or modify

provisions of existing contracts or agreements, including contracts or agreements for the sale of National Forest timber, except to the extent such changes are mutually agreed to by the parties to such contracts or agreements.

3. Pilot projects and demonstrations carried out under this section may include but are not limited to:

a. establishment and operation of utilization demonstration areas,

b. establishment and operation of fuel wood concentration and distribution centers and

c. Construction of access roads needed to facilitate wood residue utilization.

4. PROVIDED THAT: Residue removal credits may be utilizaed by the Secretary only as provided in Section 4.

SECTION 4: - The Secretary may:

1. Carry out pilot wood residue utilization projects under which purchasers of National Forest System timber under contracts awarded prior to October 1, 1986 may, except as other wise provided in this section,

(a) be required to remove wood residues not purchased by them to points of prospective use,

1. in return for compensation in the form of "residue removal credits"

2. Such projects may be carried out where the Secretary identifies situations in which pilot wood residue utilization projects on the National Forest System can provide important information on various methods and approaches to:

(a) increase the utilization in:

1. residential
2. commercial
3. industrial/or
4. powerplant applications of wood residues and

(b) where such information cannot reasonably be obtained unless the pilot projects are done in conjunction with normal National Forest timber sale activities.

3. The residue removal credits shall be applied against

a. the amount payable for the timber purchased and

b. shall represent the anticipated cost of removal of wood residues.

4. Projects carried out under this section shall apply the following guidelines:

(a) Except in cases where wood residue removal is determined to be necessary for:

1. fire prevention,
2. site preparation for regeneration,
3. wildlife habitat improvement or,
4. other land management purposes.

The Secretary may not provide for removal of wood residues in instances where the anticipated cost of removal would exceed the anticipated value.

(b) The residue removal credits authorized by this section shall not exceed the amount payable by the purchaser for timber after application of all other designated charges and credits.

(c) The Secretary is authorized to sell the wood residues removed to points of prospecitve use for not less than their appraised value.

(d) projects, demonstrations, and other programs shall be carried out in a manner which does not result in an adverse effect on the furnishing of timber free of charge under any other provision of law.

(e) Wood residues shall be collected from a site so as to avoid soil depletion or erosion giving full consideration to the protection of wildlife habitat.

(f) Sixteen USC 500 amended to read (A)' any residue removal applied under this section shall be considered as "monies received" and (B) any monies received from the sales of wood residues removed to points of prospective use shall be the proceeds of the sales, less the sum of any residue removal credit applied with respect to such residues, plus any costs incurred by the FS in processing and storing such residues.

SECTION 5: - Requires annual reports by the Secretary to the Congress submitted with reports required under section 8(c) of the Forest and Rangeland Renewable Resources Planning Act of 1974.

SECTION 6: - Secretary shall issue such regulations he deems necessary for implementation.

SECTION 7: - Definitions

1. "Anticipated cost of removal" means the projected cost of removal of wood residues from timber sales areas to points of prospective use, as determined by the Secretary at the time of advertisement of the timber sales contract in accordance with appropriate appraisal and sale procedures.

2. "Anticipated value" means the projected value of wood residues as fuel or other merchantable wood products, as determined by the Secretary at the time of advertisement of the timber sales contract in accordance with appropriate appraisal and sale procedures.

3. "Points of prospective use" means the locations where the wood residues are sold or other wise put to use, as determined by the Secretary in accordance with appropriate appraisal and sale procedures.

4. "Person" means an individual, partnership, joint-stock company, corporation, association, trust, estate, or any other legal entity, or any agency of Federal or State government or of a political subdivision of a State.

5. "Secretary" means the Secretary of Agriculture.

6. "Wood residues" includes, but is not limited to, logging slash, down timber material, woody plants, and standing live or dead trees which do not meet

utilization standards because of size, species, merchantable volume, or economic selection criteria and which, in the case of live trees, are surplus to growing stock needs.

SECTION 8: - Authorizes to be appropriated:

1. Not to exceed $25,000,000 for each fiscal year 1982, 1983, 1984, 1985, and 1986 for pilot projects, demonstrations and residue removal credits.

2. PROVIDED: Not to exceed $2,500,000 of such amount may be appropriated for administrative purposes for the period October 1, 1981, through September 30, 1986.

3. Such sums shall be in addition to those provided under other provisions of law and shall remain available until expended.

SECTION 9: - Act is effective October 1, 1981.

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